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Final Report
for the Period
July 1988 to
March1989

Gas Flows in Rocket Motors

Volume 3. Appendix D. Computer Code Listings

August 1989

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Approved for Public Release

Prepared for the **Astronautics Laboratory (AFSC)**

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FOREWORD

This is the final report for Task 1, Navier Stokes Analysis of Rocket Nozzles, for SETA contract F04611-88-C-0014 with the Astronautics Laboratory (AFSC), Edwards AFB CA. This work was performed by Pennsylvania State University as a subcontractor to Science Applications International Corporation (the SETA contractor). Dr Philip A. Kessel was the project manager for this analysis task.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the DD Form 1473.

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FIELD	GROUP	SUB-GROUP	nozzle analysis, Navier-Stokes, turbulent flow, equilibrium chemistry
20	04		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Detailed descriptions of the governing equations, the method of solution, and the computer code for calculating perfect gas or real gas flow in axisymmetric nozzles are given. The codes permit calculation of a perfect gas or a real gas for inviscid flow by solving the Euler equations, and for viscous flow by solving the thin layer Navier-Stokes equations. These equations are written in a conservative form and solved implicitly in body-fitted coordinates. The solution obtained by the conservative variables is expressed in terms of the density, ρ, the momentum parallel to the axis of symmetry (ρu), the momentum perpendicular to the axis (ρv), and the total internal energy, e_o. These variables are then used to calculate the nonconservative primitive variables, the velocity components, u and v, the pressure, p, and the temperature, T. The nozzle performance including the rate of mass flow, $\dot{m}$, the thrust, T, and the specific impulse are also computed.

The codes were written in FORTRAN V and ran on the CYBER 180/840, NOS/BE system which limited the number of grid points to 20 x 44 for solving the Euler equations and 60 x 40 for

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Block 19.

the TLNS equations. The results obtained for the nozzle flowfield showed maximum global mass flux errors of lwss than $\pm$1% for the Euler equations and less tha $\pm$2% for the TLNS equations. Solutions with more dense grids (typically 100 x 50 or higher) consistently showed global mass conservation of better than one percent.

X14140

USERID: V19 ORIGIN: PSUVM CREATED: 06/20/89 15:36:06

FILENAME: AXI2DV FOR CLASS: A FORMAT:J

SPOOLID: 2820 RECS: 2633 COPY: 1 DUPLICATE: 1

PRINTED AT: PSUVM ID: $PPCBP01 AT: 06/20/89 15:36:11

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**********************************************************************
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* THIS FILE WAS SENT BY THE COMMAND:
* PRT3812  AXI2DV FOR A1 ( PPCB1 COPIES 1 ORIENT N FONT 11
*
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FILE: AXI2DV   FOR      A1  VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STAT

//STIXXXXX JOB
//*JP T=500, L=10000
//   EXEC PGM=IEFBR14
//D DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
//      DSN=STU.I19500.MYH100.HERMES.CONV.SOLU.VIS
//D DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
//      DSN=STU.I19500.MYH100.HERMES.CONV.LINE.VIS
//D DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
//      DSN=STU.I19500.MYH100.HERMES.CONV.MASS.VIS
//  EXEC FVCG,PARM.SOURCE='OPT(3)'
//SYSIN DD *
C*************************************************************
C*      PROGRAM NAME: AXI2DV.FOR                             *
C*      AXISYMMETRIC TRANSONIC NOZZLE FLOW                   *
C*      IN GENERAL COORDINATE SYSTEM                         *
C*      USING TIME ITERATIVE CD/CD SCHEME                    *
C*      WITH THIN-LAYER APPROXIMATED NAVIER-STOKE'S EQ.      *
C*************************************************************
C*
C*   MAIN PROGRAM
C*
C*************************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************************
      CALL ERRSET(208,256,-1,0,0,0)
      CALL INITIA
      DO 10 NADV=NBEG,NEND
C     WRITE(6,*) NADV
      CALL SOLVE
      CALL CHECK
 10   CONTINUE
      CALL MASS
      CALL OUTPUT
      STOP
      END
C*
C* SET UP INITIAL CONDITION
C*
      SUBROUTINE INITIA
C*************************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
```

```
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     &              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     &            ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     &  ,ZMUT(IZ,JZ)
     &  ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     &       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      COMMON/CPCOEF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
     &              ,CPA8,CPA9,CPA10,ENE(101)
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     &           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************
      DIMENSION SS(3500,4)
      NAMELIST/INPUT/IL,JL,NEND,PO,TO,CFL,OMEGAX,OMEGAY,RM1,AIN,EST,
     &NITER,ATH,RL,THETA,CPO,GAMMAO,NBEG,ITIME,ISUP,IVISC,IWALL,RM2
     &    ,IREAD,PRN,REN,TREF,ZMUO,TWALL,FSTY,PB,PRNT,COND
C...   ISUP = 0  FOR PURE SUBSONIC FLOW
C             1  FOR TRANSONIC FLOW
C             3  FOR PURE SUPERSONIC FLOW
C...     NOT SUITABLE FOR PURE SUPERSONIC FLOW CALCULATION
C...    PB = BACK PRESSURE FOR ISUP=0
C
C ** READ INPUT DATA
      READ(5,INPUT)
      WRITE(22,INPUT)
C ** SET UP GEOMETRY
      IL1=IL-1
      JL1=JL-1
C
      CALL CPCOEF
C     WRITE(6,*) CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7,CPA8,CPA9,CPA10
C
      PI=DARCOS(-1.D0)
      C1=(AIN-ATH)/2.
      C2=(AIN+ATH)/2.
      DO 10 I=1,IL
      IF(ISUP.EQ.3)THEN
      AREA(I)=AIN+(ATH-AIN)*DFLOAT(I-1)/DFLOAT(IL1)
      ELSE
C      AREA(I)=(C1*DCOS(DFLOAT(I-1)*2.*PI/DFLOAT(IL1))+C2)*0.5
      ARR=ATH/AIN
      XX =DFLOAT(I-1)/DFLOAT(IL1)*RL
C      AREA(I)=-2.0*(ARR-1.)*XX**3+3.0*(ARR-1.)*XX**2+1.0
      AREA(I)=(ARR-1.)*(XX**2-4.*XX+4.)*XX**2+1.0
      END IF
   10 CONTINUE
      IF(IREAD.EQ.2)THEN
       DO 18 I=1,IL
       READ(38,*) X(I,1),AREA(I)
   18  CONTINUE
```

```
      ENDIF
      DO 20 I=1,IL
      DO 20 J=1,JL
      IF(IREAD.EQ.2)THEN
       X(I,J)=X(I,1)
      ELSE
      X(I,J)=DFLOAT(I-1)/DFLOAT(IL1)*RL
      ENDIF
   20 Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
      IF(FST.NE.0.DO.AND.ISUP.EQ.3)THEN
      DO=(FST-1.0)/(FST**IL1-1.)*RL
      DO 15 I=1,IL
      XL=DO*(FST**(I-1)-1.)/(FST-1.)
      AREA(I)=AIN+XL/RL*(ATH-AIN)
      DO 15 J=1,JL
      X(I,J)=XL
      Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
   15 CONTINUE
      ELSE
      ENDIF
C* STRETCH THE GRID ALONG Y-DIRECETION IN VISCOUS CASE
      IF(IVISC.EQ.1.AND.FSTY.NE.0.DO)THEN
        DO 17 I=1,IL
          Y(I,1)=0.
          DAO=(1.-FSTY)/(1.-FSTY**JL1)*AREA(I)
        DO 17 J=2,JL
          Y(I,J)=Y(I,J-1)+DAO*FSTY**(J-2)
   17   CONTINUE
      ELSE
      ENDIF
C * READ GRID FROM DATA FILE
      IF(IREAD.EQ.1)THEN
      DO 25 I=1,IL
      DO 25 J=1,JL
      READ(38)II,JJ,X(I,J),Y(I,J)
   25 CONTINUE
      ELSE
      END IF
      ATH=Y(1,JL)
      DO 125 I=2,IL
      IF(Y(I,JL).LT.ATH)THEN
        ATH=Y(I,JL)
        XTH=X(I,JL)
      ELSE
      ENDIF
  125 CONTINUE
C ** COORDINATE TRANSFORMATION
      EXI=1.0
      EYI=1.0
      DO 30 I=1,IL
      IP1=I+1
      IM1=I-1
      IF(I.EQ.1)IM1=1
      IF(I.EQ.IL)IP1=IL
      DSAI=2.*EXI
```

```
      IF(I.EQ.1.OR.I.EQ.IL)DSAI=EXI
      DO 30 J=1,JL
      JP1=J+1
      JM1=J-1
      IF(J.EQ.1)JM1=1
      IF(J.EQ.JL)JP1=JL
      DETA=2.*EYI
      IF(J.EQ.1.OR.J.EQ.JL)DETA=EYI
      XSAI=(X(IP1,J)-X(IM1,J))/DSAI
      YSAI=(Y(IP1,J)-Y(IM1,J))/DSAI
      XETA=(X(I,JP1)-X(I,JM1))/DETA
      YETA=(Y(I,JP1)-Y(I,JM1))/DETA
       IF(J.EQ.1)THEN
        XETA=XETA-0.5*(X(I,J)-2.*X(I,J+1)+X(I,J+2))
        YETA=YETA-0.5*(Y(I,J)-2.*Y(I,J+1)+Y(I,J+2))
       ELSE
       ENDIF
       IF(J.EQ.JL) THEN
       XETA=(3.D0*X(I,JL)-4.D0*X(I,JL-1)+X(I,JL-2))*0.5D0
       YETA=(3.D0*Y(I,JL)-4.D0*Y(I,JL-1)+Y(I,JL-2))*0.5D0
       ELSE
       ENDIF
      RJP=XSAI*YETA-XETA*YSAI
      RJ(I,J)=1./RJP
      SAIX(I,J)=YETA/RJP
      SAIY(I,J)=-XETA/RJP
      ETAX(I,J)=-YSAI/RJP
 30   ETAY(I,J)=XSAI/RJP
C ** INITIALIZATION
      RGAS=8314.3/20.405
      R=RGAS
      DO 991 I=1,IL
      DO 991 J=1,JL
      TTT=3061.1D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TTT)
  991 CONTINUE
C* GIVE THE INITIAL VALUE OF VISCOSTY
C     TIN=T0*(1.+0.5*GM10*RM1**2)
C     UIN=RM1*DSQRT(GAMMA0*R*TIN)
C     PIN=P0*(TIN/T0)**(GAMMA0/GM10)
C     RIN=PIN/(R*TIN)
C      ZMU0=(RIN*UIN*AREA(1)*2.)/REN
C* CALCULATE METRIC TERMS AT MID POINTS
C*
      CALL MCONST
C ** SKIP TO RERUN THE CODE
      IF(NBEG.NE.1)GOTO 300
      RM=0.04
      DO 50 I=1,IL
C#    IF(ISUP.EQ.0)THEN
C#      RMTH=RM2
C#      RM=RM1+X(I,1)/RL*2.*(RMTH-RM1)
C#      IF(X(I,1).GT.(0.5*RL))RM=RMTH-(X(I,1)-0.5*RL)/RL*2.
C#     >   *(RMTH-RM1)
```

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FILE: AXIDV   FOR      A1  VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STA

C#     ELSE
C#               RM=RM1+DFLOAT(I-1)/DFLOAT(IL1)*(RM2-RM1)
C#     END IF
       CALL ISENMA(I,ATH,XTH,RM)
       TS=T0/(1.+0.5*GM1(I,1)*RM**2)
       UU=RM*DSQRT(GAMMA(I,1)*R*TS)
       DO 50 J=1,JL
       IF(I.EQ.1.OR.I.EQ.IL)THEN
            IF(I.EQ.1)SLOPE=(Y(I+1,J)-Y(I,J))/(X(I+1,J)-X(I,J))
            IF(I.EQ.IL)SLOPE=(Y(I,J)-Y(I-1,J))/(X(I,J)-X(I-1,J))
       ELSE
         SLOPE=(Y(I+1,J)-Y(I-1,J))/(X(I+1,J)-X(I-1,J))
       END IF
       DENOM=DSQRT(1.+SLOPE*SLOPE)
       U(I,J)=UU/DENOM
       V(I,J)=UU*SLOPE/DENOM
       VN(I,J)=ETAX(I,J)*U(I,J)+ETAY(I,J)*V(I,J)
       UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
       IF(J.EQ.JL)THEN
       VN(I,J)=0.
       U(I,J)=UU/DENOM
       V(I,J)=-ETAX(I,J)/ETAY(I,J)*U(I,J)
       UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
       ELSE
       END IF
  50   CONTINUE
C* NO-SLIP INITIAL CONDITION
       IF(IVISC.EQ.1)THEN
        DO 60 I=1,IL
        U(I,JL)=0.
        V(I,JL)=0.
        UN(I,JL)=0.
        VN(I,JL)=0.
  60    CONTINUE
       ELSE
       ENDIF
       EIGMAX=0.0
       DO 80 I=1,IL
       DO 80 J=1,JL
       TS=T0-(U(I,J)**2+V(I,J)**2)/CP(I,J)*0.5
       PS=P0/(T0/TS)**(GAMMA(I,J)/GM1(I,J))
       IF(J.EQ.JL.AND.IVISC.EQ.1)THEN
         IF(IWALL.EQ.1)TS=TWALL
         PS=P(I,J-1)
       ELSE
       ENDIF
       RHO0=PS/R/TS
       RHO(I,J)=RHO0
       RHOU(I,J)=RHO(I,J)*U(I,J)
       RHOV(I,J)=RHO(I,J)*V(I,J)
       E(I,J)=RHO(I,J)*(CV(I,J)*TS+0.5*(U(I,J)**2+V(I,J)**2))
  80   P(I,J)=PS
       DO 90 I=1,IL
       DO 90 J=1,JL
       CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
```

```
      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/C0
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GOTO 210
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CY=DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*C0)/EXI
      CY=(VN(I,J)+CY*C0)/EYI
C      EIGNN=CX
C      IF(DABS(CY).GT.EIGNN)EIGNN=DABS(CY)
       EIGNN=DSQRT(CX**2+CY**2)
      IF(ITIME.EQ.1)GO TO 85
      IF(CX.GE.EIGMAX)EIGMAX=CX
      IF(CY.GT.EIGMAX)EIGMAX=CY
 85   DELTAU(I,J)=CFL/EIGNN
      GOTO 90
 210  CONTINUE
C     ZM=DSQRT((U(I,J)**2+V(I,J)**2)/C(I,J)**2)
      SX=UN(I,J)**2*(1.D0-ZM**2)**2+4.D0*(U(I,J)**2+V(I,J)**2)
     *  *(SAIX(I,J)**2+SAIY(I,J)**2)
      SY=VN(I,J)**2*(1.D0-ZM**2)**2+4.D0*(U(I,J)**2+V(I,J)**2)
     *  *(ETAX(I,J)**2+ETAY(I,J)**2)
      EIGVX=0.5D0*(UN(I,J)*(1.D0+ZM**2)+DSQRT(SX))
      EIGVY=0.5D0*(VN(I,J)*(1.D0+ZM**2)+DSQRT(SY))
      DELTAU(I,J)=CFL/DSQRT(EIGVX**2+EIGVY**2)
  90  CONTINUE
      IF(ITIME.EQ.1)RETURN
      DO 100 I=1,IL
      DO 100 J=1,JL
 100  DELTAU(I,J)=CFL/EIGMAX
      RETURN
 300  CONTINUE
 310  READ(19,720,END=1000)NDUM,(SS(NDUM,K),K=1,4)
      GOTO 310
1000  CONTINUE
      REWIND 19
      NBEG=NDUM+1
      NEND=NBEG+NITER-1
      DO 320 N=1,NDUM
 320  WRITE(19,720)N,(SS(N,K),K=1,4)
 720  FORMAT(I5,3X,4(1X,E14.7))
      DO 330 I=1,IL
      DO 330 J=1,JL
      READ(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
      TCP=0.D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     *  RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J) =GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
 330  CONTINUE
      REWIND 66
      RETURN
      END
C***************
```

```
      SUBROUTINE ISENMA(I,ATH,XTH,RM)
C*****************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     &            ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     &  ,ZMUT(IZ,JZ)
     &  ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NREG,NADV,ITIME,ISUP,IVISC,IWALL
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
C-----------------------
      ARR=(Y(I,JL)/ATH)**2
      RM1=RM*1.05
      RM2=RM*0.95
      IF(X(I,JL).GT.XTH)THEN
        RM1=RM*1.05
        RM2=RM*1.01
      ELSE
      ENDIF
      GP1=GAMMA(I,JL)+1.0
      GEXP=GP1/( 2.0-2.0*GAMMA(I,JL) )
      GSQRT=DSQRT( GAMMA(I,JL) )
      CNUM=GSQRT*(GP1/2.0)**GEXP
      ZM=RM1
       F01=ZM*GSQRT*(1.0+0.5*GM1(I,JL)*ZM*ZM)**GEXP
       F1=CNUM/F01
      ZM=RM2
       F01=ZM*GSQRT*(1.0+0.5*GM1(I,JL)*ZM*ZM)**GEXP
       F2=CNUM/F01
   10 RM3=RM1+(RM2-RM1)*(ARR-F1)/(F2-F1)
      ZM=RM3
       F01=ZM*GSQRT*(1.0+0.5*GM1(I,JL)*ZM*ZM)**GEXP
       F3=CNUM/F01
      ERR=DABS(ARR-F3)
      IF(ERR.LT.1.0D-4) GO TO 20
      RM1=RM2
      F1=F2
      RM2=RM3
      F2=F3
      GO TO 10
   20 RM=RM3
      WRITE(6,*) I,ARR,RM
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE SOLVE
C*
C*   SOLVE SUBROUTINE
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     &              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
```

```
     &                ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     &  ,ZMUT(IZ,JZ)
     &  ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON /CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     &         PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON /CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON /INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     &           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
C  RHS CALCULATION
      IF(IVISC.EQ.1)CALL MULAM
      IF(PRNT.NE.0.D0) CALL MUTUR
      CALL RHS
      IF(IVISC.EQ.1)CALL VPHS
C ** CALCULATE RESIDUAL
      DO 40 I=1,IL
      DO 40 J=1,JL
      DO 40 K=1,4
 40   DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
C*
C* ADD SAI-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C*
      IF(OMEGAX.NE.0.0D0)CALL ADDX
C*
C* ADD ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C*
      IF(OMEGAY.NE.0.0D0)CALL ADDY
C*
C* SOLVE LSAI-OPERATOR
C*
      JEND=JL
      IF(IVISC.EQ.1)JEND=JL1
      DO 50 J=2,JEND
 50   CALL COEFX(J)
C*
C* SOLVE LETA-OPERATOR
C*
      IEND=IL1
      IF(ISUP.EQ.1.OR.ISUP.EQ.3)IEND=IL
      DO 55 I=2,IEND
 55   CALL COEFY(I)
C*
C* UPDATING VARIABLES
C*
      EIGMAX=0.
      IBEG=1
      IF(ISUP.EQ.3)IBEG=2
      DO 70 I=IBEG,IL
      DO 70 J=2,JEND
      RJJ=RJ(I,J)/Y(I,J)
      DO 60 K=1,4
 60   Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
      TCP=0.D0
```

```
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GOTO 210
      CX=DSQRT(SAIX(I,J)*SAIX(I,J)+SAIY(I,J)*SAIY(I,J))
      CY=DSQRT(ETAX(I,J)*ETAX(I,J)+ETAY(I,J)*ETAY(I,J))
      CX=(UN(I,J)+CX*CO)/EXI
      CY=(VN(I,J)+CY*CO)/EYI
C      EIGNN=DABS(CX)
C      IF(DABS(CY).GT.EIGNN) EIGNN=DABS(CY)
      EIGNN=DSQRT(CX**2+CY**2)
      IF(EIGNN.GT.EIGMAX)EIGMAX=EIGNN
      DELTAU(I,J)=ITIME*CFL/EIGNN+(1-ITIME)*DELTAU(I,J)
      GOTO 70
  210 CONTINUE
      SX=UN(I,J)**2*(1.D0-ZM**2)**2+4.D0*(U(I,J)**2+V(I,J)**2)
     > *(SAIX(I,J)**2+SAIY(I,J)**2)
      SY=VN(I,J)**2*(1.D0-ZM**2)**2+4.D0*(U(I,J)**2+V(I,J)**2)
     > *(ETAX(I,J)**2+ETAY(I,J)**2)
      EIGVX=0.5D0*(UN(I,J)*(1.D0+ZM**2)+DSQRT(SX))
      EIGVY=0.5D0*(VN(I,J)*(1.D0+ZM**2)+DSQRT(SY))
      DELTAU(I,J)=CFL/DSQRT(EIGVX**2+EIGVY**2)
   70 CONTINUE
C *
C * CENTERLINE BOUNDARY CONDITIONS
      CALL CLBC
      IF(IVISC.EQ.1)CALL WALLBC
      RETURN
      END
C*
C* SUBROUTINE FOR CALCULATING METRIC TERMS
C* AT THE MIDPOINT
      SUBROUTINE MCONST
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
```

```
C*****************************************************************
      DATA FD3,OD3/1.333333333333,0.333333333333/
      DO 20 I=2,IL
      DO 20 J=1,JL1
      IF(I.EQ.IL)THEN
      XSAI=0.5*(X(I,J)+X(I,J+1)-X(I-1,J)-X(I-1,J+1))
      YSAI=0.5*(Y(I,J)+Y(I,J+1)-Y(I-1,J)-Y(I-1,J+1))
      ELSE
      YSAI=0.25*(Y(I+1,J+1)+Y(I+1,J)-Y(I-1,J+1)-Y(I-1,J))
      XSAI=0.25*(X(I+1,J+1)+X(I+1,J)-X(I-1,J+1)-X(I-1,J))
      END IF
      YETA=Y(I,J+1)-Y(I,J)
      XETA=X(I,J+1)-X(I,J)
      RJJ=1./(XSAI*YETA-XETA*YSAI)
      A1(I,J)=RJJ*(FD3*YSAI**2+XSAI**2)
      A2(I,J)=-RJJ*OD3*XSAI*YSAI
      A3(I,J)=RJJ*(YSAI**2+FD3*XSAI**2)
      A4(I,J)=RJJ*(XSAI**2+YSAI**2)
   20 CONTINUE
      RETURN
      END
C---------------------------------------------------------------
      SUBROUTINE SMOOTH
C*
C*  ADD ARTIFICIAL DISSIPATIONAL TERM FOR SAI,ETA-DIRECTION
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION ADD(4)
      DIMENSION PRE(4,4),PADD(4)
C ** SAI-DIRECTION
      ENTRY ADDX
      COEF=0.125D0*OMEGAX
      DO 70 J=1,JL
      DO 70 I=1,IL
      IF(I.EQ.1) GO TO 10
      IF(I.EQ.2) GO TO 20
      IF(I.EQ.IL1) GO TO 30
      IF(I.EQ.IL) GO TO 40
      DO 5 K=1,4
```

```
    5  ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >         +6.*Q(I,J,K)-4.*Q(I-1,J,K)
     >         +Q(I-2,J,K))
       GO TO 50
   10  DO 15 K=1,4
       QM=2.*Q(1,J,K)-Q(2,J,K)
       QMM=2.*QM-Q(1,J,K)
   15  ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >         +6.*Q(I,J,K)-4.*QM+QMM)
       GO TO 50
   20  DO 25 K=1,4
       QMM=2.*Q(1,J,K)-Q(2,J,K)
   25  ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >         +6.*Q(I,J,K)-4.*Q(I-1,J,K)
     >         +QMM)
       GO TO 50
   30  DO 35 K=1,4
       QPP=2.*Q(I+1,J,K)-Q(I,J,K)
   35  ADD(K)=COEF*(QPP-4.*Q(I+1,J,K)+6.*Q(I,J,K)
     >         -4.*Q(I-1,J,K)+Q(I-2,J,K)
     >         )
       GO TO 50
   40  DO 45 K=1,4
       QP=2.*Q(I,J,K)-Q(I-1,J,K)
       QPP=2.*QP-Q(I,J,K)
   45  ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
     >       Q(I-1,J,K)+Q(I-2,J,K))
   50  CONTINUE
       CALL PRECON(I,J,PRE)
       CALL MMV(4,PRE,ADD,PADD)
       DO 60 K=1,4
   60  DQ(I,J,K)=DQ(I,J,K)-PADD(K)/RJ(I,J)*Y(I,J)
   70  CONTINUE
       RETURN
C **
C   ADD ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C **
       ENTRY ADDY
       COEF=0.125D0*OMEGAY
       DO 170 I=1,IL
       DO 170 J=1,JL
       IF(J.EQ.1) GO TO 110
       IF(J.EQ.2) GO TO 120
       IF(J.EQ.JL1) GO TO 130
       IF(J.EQ.JL) GO TO 140
       DO 95 K=1,4
   95  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >     +6.*Q(I,J,K)-4.*Q(I,J-1,K)
     >     +Q(I,J-2,K))
       GO TO 150
  110  DO 115 K=1,4
       QM=2.*Q(I,1,K)-Q(I,2,K)
       QMM=2.*QM-Q(I,1,K)
  115  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >     +6.*Q(I,J,K)-4.*QM+QMM)
```

```
      GO TO 150
 120  DO 125 K=1,4
      QMM=2.*Q(I,1,K)-Q(I,2,K)
 125  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >   +6.*Q(I,J,K)-4.*Q(I,J-1,K)
     >    +QMM)
      GO TO 150
 130  DO 135 K=1,4
      QPP=2.*Q(I,J+1,K)-Q(I,J,K)
 135  ADD(K)=COEF*(QPP-4.*Q(I,J+1,K)+6.*Q(I,J,K)
     >   -4.*Q(I,J-1,K)+Q(I,J-2,K)
     >   )
      GO TO 150
 140  DO 145 K=1,4
      QP=2.*Q(I,J,K)-Q(I,J-1,K)
      QPP=2.*QP-Q(I,J,K)
 145  ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
     >   Q(I,J-1,K)+Q(I,J-2,K))
 150  CONTINUE
      CALL PRECON(I,J,PRE)
      CALL MMV(4,PRE,ADD,PADD)
      DO 160 K=1,4
160   DQ(I,J,K)=DQ(I,J,K)-PADD(K)/RJ(I,J)*Y(I,J)
170   CONTINUE
      RETURN
      END
C
C **  SUBROUTINE FOR CENTER LINE BOUNDARY CONDITIONS
      SUBROUTINE BC
C-----------------------------------------------------------------------
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >             P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >            ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C***********************************************************************
      DIMENSION AM(IZ),BM(IZ),CM(IZ),DM(IZ),PTEMP(IZ)
      DATA SCONST/110./
      ENTRY CLBC
C *   THE QUANTITIES EXTRAPOLATED ARE U,P,T AND LET V=0
C
      IF(ISUP.EQ.3)THEN
      I1=2
      ELSE
      I1=1
```

```
      END IF
      DO 20 I=I1,IL
      SY=SAIY(I,1)
      EY=ETAY(I,1)
      DENOM=SY-1.5*EY
      IF(I.EQ.1)THEN
      UIM1=0.
      PIM1=0.
      RIM1=1.0
      ELSE
      UIM1=U(I-1,1)
      PIM1=P(I-1,1)
      RIM1=RHO(I-1,1)
      END IF
      V(I,1)=0.
      U(I,1)=(SY*UIM1-0.5*EY*(4.*U(I,2)-U(I,3)))/DENOM
      UN(I,1)=SAIX(I,1)*U(I,1)
      VN(I,1)=ETAX(I,1)*U(I,1)
      P(I,1)=(SY*PIM1-0.5*EY*(4.*P(I,2)-P(I,3)))/DENOM
      RIV=1./RGAS
      TIM1=PIM1/RIM1*RIV
      T2=P(I,2)/RHO(I,2)*RIV
      T3=P(I,3)/RHO(I,3)*RIV
      T1=(SY*TIM1-0.5*EY*(4.*T2-T3))/DENOM
      CALL CPGAM(CP(I,1),CV(I,1),GAMMA(I,1),GM1(I,1),RGAS,I,1,
     > RHO(I,1),RHOU(I,1),RHOV(I,1),E(I,1),T1)
      RHO(I,1)=P(I,1)/T1*RIV
      RHOU(I,1)=RHO(I,1)*U(I,1)
      RHOV(I,1)=RHO(I,1)*V(I,1)
      E(I,1)=P(I,1)/GM1(I,1)+0.5*RHO(I,1)*(U(I,1)**2+V(I,1)**2)
 20   CONTINUE
      RETURN
C*
      ENTRY WALLBC
      J=JL
      IBEG=1
      IF(ISUP.EQ.3)IBEG=2
C*  SOLVE THE PRESSURE EQUATION
      IF(ISUP.NE.3)THEN
      AM(1)=0.
      BM(1)=1.5*(ETAX(1,J)**2+ETAY(1,J)**2)-(SAIX(1,J)*
     >      ETAX(1,J)+SAIY(1,J)*ETAY(1,J))
      CM(1)=SAIX(1,J)*ETAX(1,J)+SAIY(1,J)*ETAY(1,J)
      DM(1)=(ETAX(1,J)**2+ETAY(1,J)**2)*(2.*P(1,J-1)-0.5*P(1,J-2))
      ELSE
      AM(1)=0.
      BM(1)=1.
      CM(1)=0.
      DM(1)=P(1,J)
      ENDIF
      DO 30 I=2,IL1
      CC1=SAIX(I,J)*ETAX(I,J)+SAIY(I,J)*ETAY(I,J)
      CC2=ETAX(I,J)**2+ETAY(I,J)**2
      AM(I)=-0.5*CC1
      BM(I)=1.5*CC2
```

```
      CM(I)=0.5*CC1
      DM(I)=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
 30   CONTINUE
      CC1=SAIX(IL,J)*ETAX(IL,J)+SAIY(IL,J)*ETAY(IL,J)
      CC2=ETAX(IL,J)**2+ETAY(IL,J)**2
      AM(IL)=-CC1
      BM(IL)=CC1+1.5*CC2
      CM(IL)=0.
      DM(IL)=CC2*(2.*P(IL,J-1)-0.5*P(IL,J-2))
      CALL SYH(1,IL,AM,BM,CM,DM)
      DO 32 I=1,IL
 32   PTEMP(I)=DM(I)
      RIV=1./RGAS
      IF(IWALL.EQ.0)THEN
       IF(ISUP.EQ.3)THEN
        DM(1)=P(1,J)*RIV/RHO(1,J)
       ELSE
        T1=P(1,J-1)*RIV/RHO(1,J-1)
        T2=P(1,J-2)*RIV/RHO(1,J-2)
        CC2=ETAX(1,J)**2+ETAY(1,J)**2
        DM(1)=CC2*(2.*T1-0.5*T2)
       END IF
       DO 34 I=2,IL
        CC2=ETAX(I,J)**2+ETAY(I,J)**2
        T1=P(I,J-1)*RIV/RHO(I,J-1)
        T2=P(I,J-2)*RIV/RHO(I,J-2)
 34     DM(I)=CC2*(2.*T1-0.5*T2)
       CALL SYH(1,IL,AM,BM,CM,DM)
      ELSE
      ENDIF
      DO 40 I=IBEG,IL
      IF(IWALL.EQ.0)THEN
       TT=DM(I)
      ELSE
       TT=TWALL
      ENDIF
      PP=PTEMP(I)
      U(I,JL)=0.
      V(I,JL)=0.
      RHOU(I,JL)=0.
      RHOV(I,JL)=0.
      RHOO=PP*RIV/TT
      RHO(I,JL)=RHOO
      CALL CPCAM(CP(I,JL),CV(I,JL),GAMMA(I,JL),GM1(I,JL),RGAS,I,JL,
     > RHO(I,JL),RHOU(I,JL),RHOV(I,JL),E(I,JL),TT)
      E(I,JL)  =PP/GM1(I,JL)
      P(I,JL)=PP
      UN(I,JL)=0.
      VN(I,JL)=0.
 40   CONTINUE
      RETURN
C*
C*  LAMINAR VISCOSITY CALCULATION
C*
C     ENTRY MULAM
```

```
C*  USE SUTHERLAND LAW
C      DO 60 I=1,IL
C      DO 60 J=1,JL
C      TOS=TREF+SCONST
C      TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
C      TTS=TT+SCONST
C      ZMU(I,J)=ZMU0*TOS/TTS*(TT/TREF)**1.5
C       ZMU(I,J)=ZMU0
C       ZMU(I,J)=ZMU0*(TT/TREF)**0.67
C 60   CONTINUE
C      RETURN
       END
C***************
       SUBROUTINE MULAM
C***************
       IMPLICIT REAL*8(A-H,O-Z)
       PARAMETER (IZ=150,JZ=100)
       COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
       COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      >              ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      > ,ZMUT(IZ,JZ)
      > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
       COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
      >         PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
       COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
       COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
       DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
       EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
      >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
       B1=4.3222557667160623D-06
       B2=3.8885996244952953D-08
       B3=-3.7263546610032919D-12
       DO 50 NN=1,IL
       DO 50 MM=1,JL
       TT=(E(NN,MM)/RHO(NN,MM)-0.5*(U(NN,MM)**2+V(NN,MM)**2))/CV(NN,MM)
       ZMU(NN,MM)=B1+B2*TT+B3*TT*TT
 50    CONTINUE
         RETURN
         END
C
C     BOLDWIN & LOMAX TURBULENCE MODEL
C
       SUBROUTINE MUTUR
C*****************************************************************
       IMPLICIT REAL*8(A-H,O-Z)
       PARAMETER (IZ=150,JZ=100)
       COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
       COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      >     ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      > ,ZMUT(IZ,JZ)
      > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
       COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
```

```
     *         PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     *           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************
      DIMENSION YVERT(JZ),ZMUI(JZ)
      DATA AP,CCP,CKLEB,CWK,VKCON,XK/26., 1.6, .3, .25, .4, .0168/
      DATA ZMUI/JZ*0.0/
      DO 991 II=1,IL
      I=II
      FYMAX  = 0.0
      YMAX   = 0.0
      UDIF=0.
      YVERT(JL) = 0.0
      TAUW = ZMU(I,JL)*DABS(ETAY(I,JL)*(U(I,JL)-U(I,JL-1))-
     *                      ETAX(I,JL)*(V(I,JL)-V(I,JL-1)))
      CYP  = DSQRT(RHO(I,JL)*TAUW)/ZMU(I,JL)
C
      DO 10 KK = 2,JL1
      K = JL+1-KK
      YVER  = YVERT(K+1) + 1.0/DSQRT(ETAX(I,K)**2 + ETAY(I,K)**2)
      OMG   = DABS( ETAY(I,K)*(U(I,K+1)-U(I,K-1))*.5
     *             +SAIY(I,K)*(U(I,K)  -U(I-1,K))
     *             -ETAX(I,K)*(V(I,K+1)-V(I,K-1))*.5
     *             -SAIX(I,K)*(V(I,K)  -V(I-1,K))    )
      YPLUS = CYP*YVER
      TURLEN  = VKCON*YVER*(1.0D0 -DEXP(-YPLUS/AP))
      ZMUI(K) = RHO(I,K)*OMG*TURLEN**2
      FY    = TURLEN/VKCON*OMG
      UTOTAL= DSQRT(U(I,K)**2+V(I,K)**2)
      IF(UTOTAL.GE.UDIF) UDIF=UTOTAL
      IF(FY .LT. FYMAX)  GO TO 10
      FYMAX  = FY
      YMAX   = YVER
10    YVERT(K) = YVER
C
      VXDIF = UDIF
C     WRITE(6,*) II,K,TURLEN,YVER,OMG,FY,FYMAX
      FWAKE1=YMAX*FYMAX
      FWAKE2=CWK*YMAX*VXDIF**2/FYMAX
      FWAKE =DMIN1(FWAKE1,FWAKE2)
C
      DO 20 KK = 2, JL1
      K = JL+1-KK
      FKLEB    = (CKLEB*YVERT(K)/YMAX)**6
      FKLEB    = 1./(1.0 + 5.5*FKLEB)
      ZMUO     = XK*CCP*RHO(I,K)*FWAKE*FKLEB
      IF(ZMUI(K).GT.ZMUO) THEN
      ZMUTUR = ZMUO
      ELSE
      ZMUTUR = ZMUI(K)
      END IF
      ZMUT(I,K)= ZMUTUR
```

```
      ZMU(I,K)    = ZMU(I,K) + ZMUTUR
C      WRITE(77,119)K,Y(I,K),YVERT(K),U(I,K),ZMUI(K),ZMUO,ZMU(I,K)
C119   FORMAT(2X,I3,6(2X,D13.6))
20    CONTINUE
C
      ZMUT(I,1)=0.
      ZMUT(I,JL)=0.
  991 CONTINUE
      RETURN
      END
C  SUORCE TERM JACOBIAN MATRIX
      SUBROUTINE DHDQ(D,I,J)
C-----------------------------------------------------------------------
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C**********************************************************************
      DIMENSION D(4,4)
      CALL SZERO(4,D)
      IF(IVISC.EQ.0)THEN
      R2MY=0.
      ELSE
      R2MY=4./3.*ZMU(I,J)/(Y(I,J)*Y(I,J)*RHO(I,J))
      END IF
      D(3,1)=.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/Y(I,J)+IVISC*V(I,J)*R2MY
      D(3,2)=-GM1(I,J)*U(I,J)/Y(I,J)
      D(3,3)=-GM1(I,J)*V(I,J)/Y(I,J)-IVISC*R2MY
      D(3,4)=GM1(I,J)/Y(I,J)
      RETURN
      END
      SUBROUTINE JACCAL
C*
C*  SUBROUTINE FOR JACOBIAN METRIX
C*  IF IA=1, ACAP MATRIX
C*  IF IA=2, BCAP MATRIX
C*
C**********************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
```

```
     >  ,ZMUT(IZ,JZ)
     >  ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >         PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************************
      DIMENSION A(4,4),B(4,4),C(4,4)
C*************************************************************************
      ENTRY JACOB(IA,A,I,J)
      IF(IA.EQ.2)GO TO 10
      CX=SAIX(I,J)
      CY=SAIY(I,J)
      CONTRA=UN(I,J)
      GO TO 20
   10 CX=ETAX(I,J)
      CY=ETAY(I,J)
      CONTRA=VN(I,J)
   20 CONTINUE
      PHI2=0.5D0*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
      A(1,1)=0.0D0
      A(1,2)=CX
      A(1,3)=CY
      A(1,4)=0.D0
      A(2,1)=CX*PHI2-U(I,J)*CONTRA
      A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
      A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
      A(2,4)=GM1(I,J)*CX
      A(3,1)=CY*PHI2-V(I,J)*CONTRA
      A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
      A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
      A(3,4)=GM1(I,J)*CY
      A(4,1)=CONTRA*(2.D0*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
      A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA*U(I,J)
      A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA*V(I,J)
      A(4,4)=GAMMA(I,J)*CONTRA
      RETURN
C* VISCOUS TERM JACOBIAN MATRIX
C*
      ENTRY VJACOB(A,B,C,I,J)
      JP1=J+1
      JM1=J-1
      ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
      ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
      YYP =0.5*(Y(I,J)+Y(I,JP1))
      YYM =0.5*(Y(I,J)+Y(I,JM1))
      YJP =RJ(I,JP1)/Y(I,JP1)
      IF(JM1.EQ.1)THEN
      YJM=0.
      ELSE
      YJM =RJ(I,JM1)/Y(I,JM1)
      ENDIF
```

```
      IF(PRNT.EQ.0.DO) THEN
      GAMP=0.5*(GAMMA(I,J)+GAMMA(I,J+1))
      GAMM=0.5*(GAMMA(I,J)+CAMMA(I,J-1))
      GKCPP=ZMUP*GAMP/PRN
      GKCPM=ZMUM*GAMM/PRN
      ELSE
      ZMUTP = 0.5*(ZMUT(I,JP1)+ZMUT(I,J))
      ZMUTM = 0.5*(ZMUT(I,JM1)+ZMUT(I,J))
      ZMULP = ZMUP - ZMUTP
      ZMULM = ZMUM - ZMUTM
      GAMP=0.5*(GAMMA(I,J)+GAMMA(I,J+1))
      GAMM=0.5*(GAMMA(I,J)+GAMMA(I,J-1))
      GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
      GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
      ENDIF
      EXJ=ETAX(I,J)/RJ(I,J)
      EYJ=ETAY(I,J)/RJ(I,J)
      ZMUU=ZMU(I,J)
      OR=1./RHO(I,J)
      ORP=1./RHO(I,JP1)
      ORM=1./RHO(I,JM1)
      ZMURP=ZMU(I,JP1)*ORP
      ZMURM=ZMU(I,JM1)*ORM
      UR =U(I,J)*OR
      URP=U(I,JP1)*ORP
      URM=U(I,JM1)*ORM
      VR =V(I,J)*OR
      VRM=V(I,JM1)*ORM
      VRP=V(I,JP1)*ORP
      UMRP=URP*ZMU(I,JP1)
      UMRM=URM*ZMU(I,JM1)
      VMRP=VRP*ZMU(I,JP1)
      VMRM=VRM*ZMU(I,JM1)
      U2R =UR*U(I,J)
      U2RP=URP*U(I,JP1)
      U2RM=URM*U(I,JM1)
      V2R =VR*V(I,J)
      V2RP=VRP*V(I,JP1)
      V2RM=VRM*V(I,JM1)
      UVR =UR*V(I,J)
      UVRP=URP*V(I,JP1)
      UVRM=URM*V(I,JM1)
      ER2 =E(I,J)*OR**2
      ER2P=E(I,JP1)*ORP**2
      ER2M=E(I,JM1)*ORM**2
      ZRYJP=ZMURP*YJP
      ZRYJM=ZMURM*YJM
      ORYJP=ORP*YJP
      ORYJM=ORM*YJM
      VMRP=-ZMURP*V(I,JP1)*YJP
      VMRM=-ZMURM*V(I,JM1)*YJM
      URYJP=-URP*YJP
      URYJM=-URM*YJM
      VYJP=2.*ZMU(I,JP1)*VRP*YJP
      VYJM=2.*ZMU(I,JM1)*VRM*YJM
```

```
      V2YJP=-V2RP*2.*ZMU(I,JP1)*YJP
      V2YJM=-V2RM*2.*ZMU(I,JM1)*YJM
      UVYJP=-2.*ZMU(I,JP1)*UVRP*YJP
      UVYJM=-2.*ZMU(I,JM1)*UVRM*YJM
      VYJP2=VYJP*0.5
      VYJM2=0.5*VYJM
      UYJP=ZMU(I,JP1)*URP*YJP
      UYJM=ZMU(I,JM1)*URM*YJM
      AAP1= ZMUP*A1(I,J)*YYP
      AAP2= ZMUP*A2(I,J)*YYP
      AAP3= ZMUP*A3(I,J)*YYP
      AAP4= GKCPP*A4(I,J)*YYP
      AAM1= ZMUM*A1(I,JM1)*YYM
      AAM2= ZMUM*A2(I,JM1)*YYM
      AAM3 =ZMUM*A3(I,JM1)*YYM
      AAM4 =GKCPM*A4(I,JM1)*YYM
      IF(JM1.EQ.1)THEN
      CALL SZERO(4,A)
      ELSE
      A(1,1) =0.
      A(1,2) =0.
      A(1,3) =0.
      A(1,4) =0.
      A21=(AAM1*URM+AAM2*VRM)*RJ(I,JM1)/Y(I,JM1)
      A(2,1) =A21-1./3.*EXJ*VMRM
      A(2,2) =-AAM1*ORM*RJ(I,JM1)/Y(I,JM1)
      A(2,3) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)-1./3.*EXJ*ZRYJM
      A(2,4) =0.
      A31=(AAM2*URM+AAM3*VRM)*RJ(I,JM1)/Y(I,JM1)
      A(3,1) =A31+1./3.*ZMU(I,J)
     *          *EXJ*URYJM
      A(3,2) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)+1./3.*ZMU(I,J)*EXJ*ORYJM
      A(3,3) =-AAM3*ORM*RJ(I,JM1)/Y(I,JM1)
      A(3,4) =0.
      A(4,1) =(-AAM4*(-ER2M+U2RM+V2RM)+AAM1*U2RM+AAM3*V2RM+
     +          2.*AAM2*UVRM)*RJ(I,JM1)/Y(I,JM1)-
     +          1./3.*EYJ*V2YJM-1./3.*EXJ*UVYJM
      A(4,2) =AAM4*URM*RJ(I,JM1)/Y(I,JM1)-A21-1./3.*EXJ*VYJM2
      A(4,3) =AAM4*VRM*RJ(I,JM1)/Y(I,JM1)-A31-1./3.*EYJ*VYJM-
     *          1./3.*EXJ*UYJM
      A(4,4) =-AAM4*ORM*RJ(I,JM1)/Y(I,JM1)
      ENDIF
      C(1,1) =0.
      C(1,2) =0.
      C(1,3) =0.
      C(1,4) =0.
      C21=(AAP1*URP+AAP2*VRP)*RJ(I,JP1)/Y(I,JP1)
      C(2,1) =C21+1./3.*EXJ*VMRP
      C(2,2) =-AAP1*ORP*RJ(I,JP1)/Y(I,JP1)
      C(2,3) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)+1./3.*EXJ*ZRYJP
      C(2,4) =0.
      C31=(AAP2*URP+AAP3*VRP)*RJ(I,JP1)/Y(I,JP1)
      C(3,1) =C31-1./3.*ZMU(I,J)
     *          *EXJ*URYJP
      C(3,2) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)-1./3.*ZMU(I,J)*EXJ*ORYJP
```

```
      C(3,3) =-AAP3*ORP*RJ(I,JP1)/Y(I,JP1)
      C(3,4) =0.
      C(4,1) =(-AAP4*(-ER2P+U2RP+V2RP)+AAP1*U2RP+AAP3*V2RP+
     .          2.*AAP2*UVRP)*RJ(I,JP1)/Y(I,JP1)+
     .          1./3.*EYJ*V2YJP+1./3.*EXJ*UVYJP
      C(4,2) =AAP4*URP*RJ(I,JP1)/Y(I,JP1)-C21+1./3.*EXJ*VYJP2
      C(4,3) =AAP4*VRP*RJ(I,JP1)/Y(I,JP1)-C31+1./3.*EYJ*VYJP+
     .          1./3.*EXJ*UYJP
      C(4,4) =-AAP4*ORP*RJ(I,JP1)/Y(I,JP1)
      AA1  =AAP1+AAM1
      AA2  =AAP2+AAM2
      AA3  =AAP3+AAM3
      AA4  =AAP4+AAM4
      B(1,1) =0.
      B(1,2) =0.
      B(1,3) =0.
      B(1,4) =0.
      B(2,1) =(-AA1*UR-AA2*VR)*RJ(I,J)/Y(I,J)
      B(2,2) =AA1*OR*RJ(I,J)/Y(I,J)
      B(2,3) =AA2*OR*RJ(I,J)/Y(I,J)
      B(2,4) =0.
      B(3,1) =(-AA2*UR-AA3*VR)*RJ(I,J)/Y(I,J)
      B(3,2) =AA2*OR*RJ(I,J)/Y(I,J)
      B(3,3) =AA3*OR*RJ(I,J)/Y(I,J)
      B(3,4) =0.
      B(4,1) =(AA4*(-ER2+U2R+V2R)-AA1*U2R-AA3*V2R-
     .          2.*AA2*UVR)*RJ(I,J)/Y(I,J)
      B(4,2) =-AA4*UR*RJ(I,J)/Y(I,J)-B(2,1)
      B(4,3) =-AA4*VR*RJ(I,J)/Y(I,J)-B(3,1)
      B(4,4) =AA4*OR*RJ(I,J)/Y(I,J)
      RETURN
      END
C*****************************************************************
C  SUBROUTINE FOR COMPUTING PRECONDITIONER
C
      SUBROUTINE PRECON(I,J,A)
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     .              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     .             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     .  ,ZMUT(IZ,JZ)
     .  AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     .       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     .           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
      DIMENSION A(4,4)
C*****************************************************************
      CALL SZERO(4,A)
```

```
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GO TO 100
      DO 1 MM=1,4
    1 A(MM,MM)=1.0D0
      RETURN
  100 CONTINUE
      ALPHA=U(I,J)*U(I,J)+V(I,J)*V(I,J)
      CON=CO*CO/ALPHA
      CONM1=CON-1.0D0
      A(1,1)=1.0D0
      A(2,2)=1.0D0
      A(3,3)=1.0D0
      A(4,1)=0.5D0*ALPHA*CONM1
      A(4,2)=-U(I,J)*CONM1
      A(4,3)=-V(I,J)*CONM1
      A(4,4)=CON
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE EIGEN(IA,A,I,J)
C*
C*  SUBROUTINE FOR EIGENVECTOR MATRIX CALCULATION
C*  IF IA=1  L FOR ACAP
C*  IF IA=2  L FOR BCAP
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION A(4,4),C(IZ,JZ)
C*****************************************************************
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      C(I,J)=CO
      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
C*
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GO TO 500
C*
C*    EIGENVECTOR FOR ORIGINAL EULER EQN
C*
      IF(IA.EQ.2)GO TO 10
      CX=SAIX(I,J)
```

```
      CY=SAIY(I,J)
      GO TO 20
   10 CX=ETAX(I,J)
      CY=ETAY(I,J)
   20 CONTINUE
      SQ2=DSQRT(2.D0)
C     C=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      C1=CX/DSQRT(CX**2+CY**2)
      C2=CY/DSQRT(CX**2+CY**2)
      A(1,1)=1.-0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/C0**2
      A(1,2)=GM1(I,J)*U(I,J)/C0**2
      A(1,3)=GM1(I,J)*V(I,J)/C0**2
      A(1,4)=-GM1(I,J)/C0**2
      A(2,1)=(-C2*U(I,J)+C1*V(I,J))/RHO(I,J)
      A(2,2)=C2/RHO(I,J)
      A(2,3)=-C1/RHO(I,J)
      A(2,4)=0.
      A(3,1)=-(C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+
     >       0.5/SQ2*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/RHO(I,J)/C0
      A(3,2)=C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/C0
      A(3,3)=C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/C0
      A(3,4)=GM1(I,J)/SQ2/RHO(I,J)/C0
      A(4,1)=(C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+0.5/SQ2*GM1(I,J)*
     >       (U(I,J)**2+V(I,J)**2)/RHO(I,J)/C0
      A(4,2)=-C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/C0
      A(4,3)=-C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/C0
      A(4,4)=GM1(I,J)/SQ2/RHO(I,J)/C0
      GOTO 600
C
C
  500 CONTINUE
C*
C* EIGENVECTOR FOR PRECONDITIONED EULER EQN
C*
      IF(IA.EQ.2) GO TO 50
      IF(IA.NE.1) STOP 999
      CX=SAIX(I,J)
      CY=SAIY(I,J)
      CONTRA=UN(I,J)
      GO TO 60
   50 CX=ETAX(I,J)
      CY=ETAY(I,J)
      CONTRA=VN(I,J)
   60 CONTINUE
      UU=U(I,J)**2+V(I,J)**2
      XM=DSQRT(UU/C(I,J)**2)
      QM=1.D0-XM**2
      XMM=QM**2
      AC=DSQRT(CONTRA**2*XMM+4.D0*C(I,J)**2*XM**2
     > *(CX**2+CY**2))
      A(1,1)=0.5D0+0.5D0*(V(I,J)*CX-U(I,J)*CY)/(RHO(I,J)*
     > (CX**2+CY**2))-2.D0*QM*CONTRA**2/(XMM*CONTRA**2-AC**2)
     > +GM1(I,J)*UU*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(1,2)=0.5D0*CY/(RHO(I,J)*(CX**2+CY**2))+2.D0*
     > CX*QM*CONTRA/(XMM*CONTRA**2-AC**2)
```

```
     > -GM1(I,J)*U(I,J)*2.D0*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(1,3)=-0.5D0*CX/(RHO(I,J)*(CX**2+CY**2))+2.D0*CY*QM*CONTRA
     > /(XMM*CONTRA**2-AC**2)
     > -GM1(I,J)*V(I,J)*2.D0*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(1,4)=2.D0*GM1(I,J)*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(2,1)=0.5D0+0.5D0*(U(I,J)*CY-V(I,J)*CX)/(RHO(I,J)
     > *(CX**2+CY**2))
     > -2.D0*QM*CONTRA**2/(XMM*CONTRA**2-AC**2)
     > +GM1(I,J)*UU*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(2,2)=-0.5D0*CY/(RHO(I,J)*(CX**2+CY**2))+2.D0*CX*QM*CONTRA/
     > (XMM*CONTRA**2-AC**2)
     > -GM1(I,J)*U(I,J)*2.D0*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(2,3)=0.5D0*CX/(RHO(I,J)*(CX**2+CY**2))+2.D0*CY*QM*CONTRA/
     > (XMM*CONTRA**2-AC**2)
     > -GM1(I,J)*V(I,J)*2.D0*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(2,4)=2.D0*GM1(I,J)*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
      A(3,1)=((QM*CONTRA+AC)*CONTRA-GM1(I,J)*UU*(CX**2+CY**2))
     > /(AC*(QM*CONTRA-AC))
      A(3,2)=(-CX*(QM*CONTRA+AC)+2.D0*GM1(I,J)*U(I,J)*(CX**2+CY**2))
     > /(AC*(QM*CONTRA-AC))
      A(3,3)=(-CY*(QM*CONTRA+AC)+2.D0*GM1(I,J)*V(I,J)*(CX**2+CY**2))
     > /(AC*(QM*CONTRA-AC))
      A(3,4)=-2.D0*GM1(I,J)*(CX**2+CY**2)/(AC*(QM*CONTRA-AC))
      A(4,1)=(CONTRA*(QM*CONTRA-AC)-GM1(I,J)*UU*(CX**2+CY**2))
     > /(AC*(QM*CONTRA+AC))
      A(4,2)=(-CX*(QM*CONTRA-AC)+2.D0*GM1(I,J)*U(I,J)*(CX**2+CY**2))
     > /(AC*(QM*CONTRA+AC))
      A(4,3)=(-(QM*CONTRA-AC)*CY+2.D0*GM1(I,J)*V(I,J)*(CX**2+CY**2))
     > /(AC*(QM*CONTRA+AC))
      A(4,4)=-2.D0*GM1(I,J)*(CX**2+CY**2)/(AC*(QM*CONTRA+AC))
  600 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE COEFX(J)
C*
C*   SETTING COEFFICIENTS FOR LX-OPERATOR
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >            ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
```

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FILE: AXI2DV   FOR      A1  VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STAT

      DIMENSION IN(4),EE(4,4,IZ),EL(4,IZ),W(4,IZ)
      DIMENSION AM(4,4),BM(4,4),CM(4,4),DM(4)
      DIMENSION AL(4,4),BE(4)
      DIMENSION A(4,4),AL1(4,4),D(4,4)
C
      DIMENSION PA(4,4),PPD(4,4),PINV(4,4),PRE(4,4),AL2(4,4)
      DIMENSION AM1(4,4),BM1(4,4),CM1(4,4),DM1(4),PIA(4,4)
      DIMENSION E1(4,4),EINV(4,4),AA(4,4),GA(4,4),GA1(4,4),EG(4,4)
     > ,AINV(4,4)
C**************************************************************
C*
C* UPSTREAM BOUNDARY CONDITION AT I=1
C*
      I=1
      TAUD=DELTAU(I,J)*THETA/EXI
      IF(ISUP.EQ.3)GOTO 45
      CALL SZERO(4,AM)
      CALL JACOB(1,A,I,J)
      CALL DHDQ(D,I,J)
      CALL PRECON(I,J,PRE)
      CALL EIGEN(1,AL1,I,J)
      DO 951 M=1,3
      DO 951 N=1,4
  951 AL1(M,N)=0.D0
      DO 901 MM=1,4
      DO 901 NN=1,4
      PPD(MM,NN)=PRE(MM,NN)-TAUD*D(MM,NN)
  901 CONTINUE
      CALL INVER(4,PPD,PINV)
      CALL MMM(4,PINV,A,PA)
      CALL MMM(4,AL1,PA,PIA)
      CALL SZERO(4,BM)
      DO 10 M=1,4
      DO 10 N=1,4
      BM(M,N)=AL1(M,N)-TAUD*PIA(M,N)
   10 CONTINUE
      RJYY=RJ(I,J)/Y(I,J)
      RCV=RHO(I,J)*CV(I,J)
      RJRCV=RJYY/RCV
      BM(1,1)=(-E(I,J)/RHO(I,J)+GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
     > +V(I,J)**2))*RJRCV
      BM(1,2)=-GM1(I,J)/GAMMA(I,J)*U(I,J)*RJRCV
      BM(1,3)=-GM1(I,J)/GAMMA(I,J)*V(I,J)*RJRCV
      BM(1,4)=RJRCV
C      BM(2,1)=-GAMMA(I,J)*E(I,J)/RHO(I,J)+(GAMMA(I,J)+1.)*AAA
C      BM(2,2)=-U(I,J)
C      BM(2,3)=-V(I,J)
C      BM(2,4)=1.D0
      C1=(RHO(I,J)*E(I,J)-0.5*RHO(I,J)**2*(U(I,J)**2+V(I,J)**2))
      C2=(RHO(I,J)*E(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*RHO(I,J)**2*(U(I,J)**2
     >    +V(I,J)**2))
      C3=(C2/C1)**(GAMMA(I,J)/GM1(I,J))
      C4=GAMMA(I,J)/GM1(I,J)/C1*(C2/C1)**(1.D0/GM1(I,J))
      BM(2,1)=(0.5*(U(I,J)**2+V(I,J)**2)*C3+C4*E(I,J)*(C1-C2)/RHO(I,J)
     >  )*GM1(I,J)*RJYY
```

```
      BM(2,2)=(-U(I,J)*C3+C4*U(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
     > *GM1(I,J)*RJYY
      BM(2,3)=(-V(I,J)*C3+C4*V(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
     > *GM1(I,J)*RJYY
      BM(2,4)=(C3+C4*(C1-C2))*GM1(I,J)*RJYY
      BM(3,1)=-VN(I,J)*RJYY/RHO(I,J)
      BM(3,2)=ETAX(I,J)*RJYY/RHO(I,J)
      BM(3,3)=ETAY(I,J)*RJYY/RHO(I,J)
      BM(3,4)=0.
      CALL SZERO(4,CM)
      CALL JACOB(1,A,I+1,J)
      CALL MMM(4,PINV,A,PA)
      CALL MMM(4,AL1,PA,PIA)
      DO 20 M=1,4
      DO 20 N=1,4
      CM(M,N)=-TAUD*PIA(M,N)
   20 CONTINUE
      DO 971 M=1,3
      DO 971 N=1,4
  971 CM(M,N)=0.D0
C*
      CALL MMM(4,AL1,PINV,AL2)
      DO 952 M=1,4
  952 DM1(M)=DQ(I,J,M)
      CALL MMV(4,AL2,DM1,DM)
C*
      TON=(E(I,J)/RHO(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
     > +V(I,J)**2))/CV(I,J)
      TT =(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
      PON=P(I,J)*(TON/TT)**(GAMMA(I,J)/GM1(I,J))
      DM(1)= (TO-TON)
      DM(2)= (PO-PON)
      DM(3)= -VN(I,J)
      GOTO 49
   45 CONTINUE
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      CALL SZERO(4,CM)
      DO 46 M=1,4
      DM(M)=0.
      BM(M,M)=1.0
   46 CONTINUE
   49 CONTINUE
      CALL EEL(I,4,IL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
C*
C* INTERIOR NODES
C*
      DO 70 I=2,IL1
      TAUD=0.5D0*DELTAU(I,J)*THETA/EXI
      TAUD2=2.*TAUD
      IM1=I-1
      IP1=I+1
      CALL PRECON(I,J,PRE)
      CALL JACOB(1,A,IM1,J)
      CALL DHDQ(D,I,J)
```

```
      DO 902 MM=1,4
      DO 902 NN=1,4
      PPD(MM,NN)=PRE(MM,NN)-TAUD2*D(MM,NN)
  902 CONTINUE
      CALL INVER(4,PPD,PINV)
      CALL MMM(4,PINV,A,PA)
      CALL SMM(4,TAUD,PA,AM)
      CALL SZERO(4,BM)
      DO 50 M=1,4
   50 BM(M,M)=BM(M,M)+1.
      CALL JACOB(1,A,IP1,J)
      CALL MMM(4,PINV,A,PA)
      CALL SMM(4,-TAUD,PA,CM)
      DO 961 M=1,4
  961 DM1(M)=DQ(I,J,M)
      CALL MMV(4,PINV,DM1,DM)
C
C
      CALL EEL(I,4,IL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
   70 CONTINUE
C*
C* DOWNSTREAM BOUDARY CONDITION AT I=IL
C*
      I=IL
      TAUD=DELTAU(I,J)*THETA/EXI
      CALL JACOB(1,A,I-1,J)
      CALL DHDQ(D,I,J)
      CALL PRECON(I,J,PRE)
      DO 903 MM=1,4
      DO 903 NN=1,4
      PPD(MM,NN)=PRE(MM,NN)-TAUD*D(MM,NN)
  903 CONTINUE
      CALL INVER(4,PPD,PINV)
      IF(ISUP.EQ.1.OR.ISUP.EQ.3) GO TO 75
      CALL EIGEN(1,AL1,I,J)
      DO 71 N=1,4
   71 AL1(4,N)=0.0D0
      CALL MMM(4,AL1,PA,AM1)
      CALL SMM(4,TAUD,AM1,AM)
      CALL JACOB(1,A,I,J)
      CALL MMM(4,PINV,A,PA)
C     DO 78 M=1,4
C     DO 78 N=1,4
C 78  A(M,N)=A(M,N)-D(M,N)
      CALL MMM(4,AL1,PA,BM)
      DO 72 M=1,4
      DO 72 N=1,4
   72 BM(M,N)=BM(M,N)*TAUD+AL1(M,N)
      BM(4,1)=0.5*(U(I,J)*U(I,J)+V(I,J)*V(I,J))
      BM(4,2)=-U(I,J)
      BM(4,3)=-V(I,J)
      BM(4,4)=1.
      CALL SZERO(4,CM)
      CALL MMM(4,AL1,PINV,AL2)
      DO 73 M=1,4
```

```
      DM(M)=0.
      DO 73 K=1,4
   73 DM(M)=DM(M)+AL2(M,K)*DQ(I,J,K)
      IF(PB.NE.0.D0)THEN
      DM(4)= (PB-P(IL,J))/GM1(IL,J)*Y(IL,J)/RJ(IL,J)
      ENDIF
      GO TO 95
   75 CONTINUE
      CALL MMM(4,PINV,A,PA)
      CALL SMM(4,TAUD,PA,AM)
      CALL JACOB(1,A,I,J)
      CALL MMM(4,PINV,A,PA)
      CALL SMM(4,TAUD,PA,BM)
      DO 80 M=1,4
   80 BM(M,M)=BM(M,M)+1.
      CALL SZERO(4,CM)
      DO 90 K=1,4
   90 DM1(K)=DQ(I,J,K)
      CALL MMV(4,PINV,DM1,DM)
   95 CONTINUE
      CALL EEL(I,4,IL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
C*
C* SOLVE 4*4 BLOCK TRIDIAGONAL SYSTEM
C*
      CALL SOLU(W,IL,4,EE,EL)
      DO 100 I=1,IL
      DO 100 K=1,4
      DQ(I,J,K)=W(K,I)
  100 CONTINUE
C* MULTIPY DQ BY I-DT*D
C     I2=IL
C     IF(ISUP.EQ.0)I2=IL1
C     DO 200 I=2,I2
C     CALL SZERO(4,BM)
C     CALL DHDQ(D,I,J)
C     DO 120 M=1,4
C     BM(M,M)=BM(M,M)+1.0
C     DO 120 N=1,4
C     BM(M,N)=BM(M,N)-DELTAU(I,J)*D(M,N)
C 120 CONTINUE
C     DO 140 K=1,4
C     DM(K)=0.
C     DO 140 N=1,4
C     DM(K)=DM(K)+BM(K,N)*W(N,I)
C 140 CONTINUE
C     DO 160 K=1,4
C 160 DQ(I,J,K)=DM(K)
C 200 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE COEFY(I)
C*
C*  SETTING COEFFICIENTS FOR LY-OPERATOR
C*
```

```
C*************************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************************
      DIMENSION IN(4),EE(4,4,JZ),EL(4,JZ),W(4,JZ)
      DIMENSION AM(4,4),BM(4,4),CM(4,4),DM(4)
      DIMENSION AL(4,4),BE(4)
      DIMENSION B(4,4),BL1(4,4),D(4,4),A(4,4)
CHOI
      DIMENSION AMJL(4,4),BMJL(4,4),CMJL(4,4),DMJL(4)
      DIMENSION PINV(4,4),PPD(4,4),PRE(4,4),PINV1(4,4),PPDJL1(4,4)
     > ,PID(4,4),PIA(4,4),PIB(4,4),DM1(4),DM2(4),DM10(4),DM20(4)
C*************************************************************************
C*
C* ON THE CENTER LINE OF THE NOZZLE AT J=1
C*
      J=1
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      DO 20 M=1,4
      DM(M)=0.
      BM(M,M)=BM(M,M)+1.0
 20   CONTINUE
      CALL SZERO(4,CM)
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
C*
C* INTERIOR NODS
C*
      DO 80 J=2,JL1
      TAUD=0.5D0*DELTAU(I,J)*THETA/EYI
      TAUD2=2.*TAUD
      JM1=J-1
      JP1=J+1
      CALL JACOB(2,B,I,JM1)
      CALL PRECON(I,J,PRE)
      CALL DHDQ(D,I,J)
      DO 904 MM=1,4
      DO 904 NN=1,4
      PPD(MM,NN)=PRE(MM,NN)-TAUD2*D(MM,NN)
 904  CONTINUE
      CALL INVER(4,PPD,PINV)
      CALL MMM(4,PINV,B,PIB)
```

```
      CALL SMM(4,TAUD,PIB,AM)
      CALL SZERO(4,BM)
      DO 60 M=1,4
   60 BM(M,M)=BM(M,M)+1.
      CALL JACOB(2,B,I,JP1)
      CALL MMM(4,PINV,B,PIB)
      CALL SMM(4,-TAUD,PIB,CM)
C*
C*  INSERT VISCOUS JACOBIAN LHS HERE
C*
      IF(IVISC.EQ.1)THEN
       CALL VJACOB(A,B,D,I,J)
      CALL MMM(4,PINV,A,PIA)
      CALL MMM(4,PINV,B,PIB)
      CALL MMM(4,PINV,D,PID)
        DO 68 M=1,4
        DO 68 N=1,4
         AM(M,N)=AM(M,N)-DELTAU(I,J)*PIA(M,N)
         BM(M,N)=BM(M,N)+DELTAU(I,J)*PIB(M,N)
   68    CM(M,N)=CM(M,N)-DELTAU(I,J)*PID(M,N)
      ELSE
      END IF
      DO 70 K=1,4
   70 DM(K)=DQ(I,J,K)
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
   80 CONTINUE
C*
C* WALL  BOUNDARY CONDITION
C*
CHOI       J=JL
CHOI       TAUD=THETA*DELTAU(I,J)/EYI
CHOI       IF(IVISC.EQ.1)GOTO 111
CHOI       CALL SZERO(4,AM)
CHOI       CALL JACOB(2,B,I,J-1)
CHOI       CALL EIGEN(2,BL1,I,J)
CHOI       DO 90 M=1,3
CHOI       DO 90 N=1,4
CHOI       DO 90 K=1,4
CHOI   90  AM(M,N)=AM(M,N)+TAUD*BL1(M,K)*B(K,N)
CHOI       CALL SZERO(4,BM)
CHOI       CALL JACOB(2,B,I,J)
CHOI       CALL DHDQ(D,I,J)
CHOI       DO 100 M=1,3
CHOI       DO 100 N=1,4
CHOI       BM(M,N)=BM(M,N)+BL1(M,N)
CHOI       DO 100 K=1,4
CHOI       BM(M,N)=BM(M,N)+TAUD*BL1(M,K)*(B(K,N)-D(K,N))
CHOI 100   CONTINUE
CHOI
CHOI
      J=JL
      TAUJL=DELTAU(I,JL)
      TAUJM=DELTAU(I,JL1)
      CALL PRECON(I,JL1,PRE)
      CALL DHDQ(D,I,JL1)
```

```
      DO 905 MM=1,4
      DO 905 NN=1,4
      PPDJL1(MM,NN)=PRE(MM,NN)-TAUJM*D(MM,NN)
  905 CONTINUE
      CALL PRECON(I,JL,PRE)
      CALL DHDQ(D,I,JL)
      DO 906 MM=1,4
      DO 906 NN=1,4
      PPD(MM,NN)=PRE(MM,NN)-TAUJL*D(MM,NN)
  906 CONTINUE
      IF(IVISC.EQ.1) GOTO 111
      CALL SZERO(4,AMJL)
      CALL JACOB(2,B,I,J-1)
      CALL EIGEN(2,BL1,I,J)
      DO 1105 N=1,4
      BL1(4,N)=0.D0
 1105 CONTINUE
      DO 1101 M=1,4
      DO 1101 N=1,4
      AMJL(M,N)=-TAUJL*(PPDJL1(M,N)-2.D0*TAUJM*B(M,N))
 1101 CONTINUE
      CALL MMM(4,BL1,AMJL,AM)
      CALL SZERO(4,BMJL)
      CALL JACOB(2,B,I,J)
      DO 1201 M=1,4
      DO 1201 N=1,4
      BMJL(M,N)=TAUJM*(PPD(M,N)+2.D0*TAUJL*B(M,N))
 1201 CONTINUE
      CALL MMM(4,BL1,BMJL,BM)
      CALL SZERO(4,CM)
      DO 1501 MM=1,4
      DM1(MM)=DQ(I,JL,MM)
 1501 CONTINUE
      DO 1502 MM=1,4
      DM2(MM)=DQ(I,JL1,MM)
 1502 CONTINUE
      CALL MMV(4,PPD,DM1,DM10)
      CALL MMV(4,PPDJL1,DM2,DM20)
      DO 1300 M=1,4
      DMJL(M)=TAUJM*DM10(M)+TAUJL*DM20(M)
 1300 CONTINUE
      CALL MMV(4,BL1,DMJL,DM)
CHOI
CHOI
      BM(4,1)=-VN(I,J)
      BM(4,2)=ETAX(I,J)
      BM(4,3)=ETAY(I,J)
      BM(4,4)=0.
      CALL SZERO(4,CM)
CHOI       DO 110 M=1,3
CHOI       DM(M)=0.
CHOI       DO 110 K=1,4
CHOI       DM(M)=DM(M)+BL1(M,K)*DQ(I,J,K)
CHOI  110  CONTINUE
      DM(4)=0.
```

```
      GOTO 119
 111  CONTINUE
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      CALL SZERO(4,CM)
      DO 113 M=1,4
      DM(M)=0.
 113  BM(M,M)=1.0
 119  CONTINUE
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
C*
C* SOLVE 4*4 BLOCK TRIDIAGONAL MATRICS
C*
      CALL SOLU(W,JL,4,EE,EL)
      DO 120 J=1,JL
      DO 120 K=1,4
      DQ(I,J,K)=W(K,J)
  120 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE FLUXCL
C*
C* SUBROUTINE FOR FLUX VECTOR CALCULATION
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >            ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >        PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      ENTRY FLUX
C*
C* COMPUTE CONVECTIVE TERMS
C*
      DO 10 I=1,IL
      DO 10 J=1,JL
      F(I,J,1)=RHO(I,J)*UN(I,J)/RJ(I,J)*Y(I,J)
      F(I,J,2)=(RHOU(I,J)*UN(I,J)+SAIX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      F(I,J,3)=(RHOV(I,J)*UN(I,J)+SAIY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      F(I,J,4)=(E(I,J)+P(I,J))*UN(I,J)/RJ(I,J)*Y(I,J)
      G(I,J,1)=RHO(I,J)*VN(I,J)/RJ(I,J)*Y(I,J)
      G(I,J,2)=(RHOU(I,J)*VN(I,J)+ETAX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      G(I,J,3)=(RHOV(I,J)*VN(I,J)+ETAY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
```

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FILE: AXIZDV   FOR      A1  VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STA

      G(I,J,4)=(E(I,J)+P(I,J))*VN(I,J)/RJ(I,J)*Y(I,J)
   10 CONTINUE
      RETURN
C* VISCOUS FLUX VECTOR
C*
      ENTRY VFLUX
      DO 30 I=2,IL
      DO 30 J=2,JL1
      JP1=J+1
      JM1=J-1
      ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
      ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
      IF(PRNT.EQ.0.DO) THEN
      GAMP=0.5*(GAMMA(I,J)+GAMMA(I,JP1))
      GAMM=0.5*(GAMMA(I,J)+GAMMA(I,JM1))
      GKCPP=ZMUP*GAMP/PRN
      GKCPM=ZMUM*GAMM/PRN
      ELSE
      ZMUTP = 0.5*(ZMUT(I,JP1)+ZMUT(I,J))
      ZMUTM = 0.5*(ZMUT(I,JM1)+ZMUT(I,J))
      ZMULP = ZMUP - ZMUTP
      ZMULM = ZMUM - ZMUTM
      GAMP=0.5*(GAMMA(I,J)+GAMMA(I,JP1))
      GAMM=0.5*(GAMMA(I,J)+GAMMA(I,JM1))
      GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
      GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
      ENDIF
      YYP=0.5*(Y(I,J)+Y(I,JP1))
      YYM=0.5*(Y(I,J)+Y(I,JM1))
      YZP=YYP*ZMUP
      YZM=YYM*ZMUM
      AAP1=A1(I,J)*YZP
      AAM1=A1(I,JM1)*YZM
      AAP2=A2(I,J)*YZP
      AAM2=A2(I,JM1)*YZM
      AAP3=A3(I,J)*YZP
      AAM3=A3(I,JM1)*YZM
      AAP4=A4(I,J)*YYP*GKCPP
      AAM4=A4(I,JM1)*YYM*GKCPM
      UP=U(I,JP1)-U(I,J)
      UM=-U(I,JM1)+U(I,J)
      VP=V(I,JP1)-V(I,J)
      VM=V(I,J)-V(I,JM1)
      ERP=E(I,JP1)/RHO(I,JP1)-E(I,J)/RHO(I,J)
      ERM=E(I,J)/RHO(I,J)-E(I,JM1)/RHO(I,JM1)
      U2P=U(I,JP1)**2-U(I,J)**2
      U2M=U(I,J)**2-U(I,JM1)**2
      V2P=V(I,JP1)**2-V(I,J)**2
      V2M=V(I,J)**2-V(I,JM1)**2
      UVP=U(I,JP1)*V(I,JP1)-U(I,J)*V(I,J)
      UVM=U(I,J)*V(I,J)-U(I,JM1)*V(I,JM1)
      G(I,J,1)=0.
      G(I,J,2)=(AAP1*UP-AAM1*UM)+(AAP2*VP-AAM2*VM)
      G(I,J,3)=(AAP2*UP-AAM2*UM)+(AAP3*VP-AAM3*VM)
      G(I,J,4)=(AAP4*ERP-AAM4*ERM)+0.5*((AAP1-AAP4)*U2P-
```

```
     >    (AAM1-AAM4)*U2M)+0.5*((AAP3-AAP4)*V2P-(AAM3-AAM4)*V2M)+
     >    (AAP2*UVP-AAM2*UVM)
C*
C* INSERT THE EXTRA FIRST ORDER TERMS IN CYLINDRICAL COORDINATE
C*  SYSTEMS
C*
      EYJ=ETAY(I,J)/RJ(I,J)
      EXJ=ETAX(I,J)/RJ(I,J)
      DMUV=0.5*(ZMU(I,JP1)*V(I,JP1)-ZMU(I,JM1)*V(I,JM1))
      DDV =0.5*(V(I,JP1)-V(I,JM1))
      DMUV2=0.5*(ZMU(I,JP1)*V(I,JP1)**2-ZMU(I,JM1)*V(I,JM1)**2)
      DMUUV=0.5*(ZMU(I,JP1)*U(I,JP1)*V(I,JP1)-
     *           ZMU(I,JM1)*U(I,JM1)*V(I,JM1))
      DDU =0.5*(U(I,JP1)-U(I,JM1))
      DDMU=0.5*(ZMU(I,JP1)-ZMU(I,JM1))
      G(I,J,2)=G(I,J,2)-2./3.*EXJ*DMUV
      G(I,J,3)=G(I,J,3)+2./3.*(ZMU(I,J)*EXJ*DDU-V(I,J)*EYJ*DDMU)
      G(I,J,4)=G(I,J,4)-2./3.*(EYJ*DMUV2+EXJ*DMUUV)
  30  CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
C **  RIGHT HAND SIDE CALCULATION
C-----------------------------------------------------------------
      SUBROUTINE RHSCL
C ****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >            ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >       PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C****************************************************************
      ENTRY RHS
      CALL FLUX
      EXII=2.*EXI
      EYII=EYI*2.
      DO 10 I=1,IL
      DO 10 J=1,JL
      DO 10 K=1,4
 10   DQ(I,J,K)=0.
      I=1
      DO 30 J=1,JL
      DO 20 K=1,4
C 20   DQ(I,J,K)=DQ(I,J,K)+(-3.*F(I,J,K)+4.*F(I+1,J,K)-
C     >          F(I+2,J,K))/EXII
```

```
   20  DQ(I,J,K)=DQ(I,J,K)+(F(I+1,J,K)-F(I,J,K))/EXI
       IF(J.EQ.1.OR.J.EQ.JL) GO TO 30
       DO 25 K=1,4
   25  DQ(I,J,K)=DQ(I,J,K)+(G(I,J+1,K)-G(I,J-1,K))/EYII
   30  CONTINUE
       J=1
       DO 50 I=1,IL
       DO 40 K=1,4
C  40   DQ(I,J,K)=DQ(I,J,K)+(-3.*G(I,J,K)+4.*G(I,J+1,K)-
C    >              G(I,J+2,K))/EYII
   40  DQ(I,J,K)=DQ(I,J,K)+(G(I,J+1,K)-G(I,J,K))/EYI
       IF(I.EQ.1.OR.I.EQ.IL) GO TO 50
       DO 45 K=1,4
   45  DQ(I,J,K)=DQ(I,J,K)+(F(I+1,J,K)-F(I-1,J,K))/EXII
   50  CONTINUE
       I=IL
       DO 70 J=1,JL
       DO 60 K=1,4
C  60   DQ(I,J,K)=DQ(I,J,K)+(F(I-2,J,K)-4.*F(I-1,J,K)+
C    >              3.*F(I,J,K))/EXII
   60  DQ(I,J,K)=DQ(I,J,K)+(F(I,J,K)-F(I-1,J,K))/EXI
       IF(J.EQ.1.OR.J.EQ.JL) GO TO 70
       DO 65 K=1,4
   65  DQ(I,J,K)=DQ(I,J,K)+(G(I,J+1,K)-G(I,J-1,K))/EYII
   70  CONTINUE
       J=JL
       DO 90 I=1,IL
       DO 80 K=1,4
CHG1
   80  DQ(I,J,K)=DQ(I,J,K)+(G(I,J-2,K)-4.*G(I,J-1,K)+
     >             3.*G(I,J,K))/EYII
CHG1 80   DQ(I,J,K)=DQ(I,J,K)+(G(I,J,K)-G(I,J-1,K))/EYI
       IF(I.EQ.1.OR.I.EQ.IL) GO TO 90
       DO 85 K=1,4
   85  DQ(I,J,K)=DQ(I,J,K)+(F(I+1 J,K)-F(I-1,J,K))/EXII
   90  CONTINUE
       DO 100 I=2,IL1
       DO 100 J=2,JL1
       IP1=I+1
       IM1=I-1
       JP1=J+1
       JM1=J-1
       DO 100 K=1,4
       DQ(I,J,K)=DQ(I,J,K)+(F(IP1,J,K)-F(IM1,J,K))/EXII+
     >             (G(I,JP1,K)-G(I,JM1,K))/EYII
  100  CONTINUE
       DO 200 I=1,IL
       DO 200 J=2,JL
       DQ(I,J,3)=DQ(I,J,3)-P(I,J)/RJ(I,J)
  200  CONTINUE
       RETURN
C* VISCOUS RIGHT HAND SIDE
C*
       ENTRY VRHS
       CALL VFLUX
```

```
      DO 300 I=2,IL
      DO 300 J=2,JL1
      DQ(I,J,3)=DQ(I,J,3)+4./3.*ZMU(I,J)*V(I,J)/(RJ(I,J)*Y(I,J))
      DO 300 K=2,4
 300  DQ(I,J,K)=DQ(I,J,K)-G(I,J,K)
      RETURN
      END
C ***************************************************************
C    SERVICE SUBROUTINE
C ***************************************************************
      SUBROUTINE SUPPLY
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >             ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,ZMUT(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >        PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C***************************************************************
      DIMENSION SS(4),SS1(4),SS2(4)
      ENTRY CHECK
      DO 10 K=1,4
      SS1(K)=0.D0
  10  SS2(K)=0.D0
      IF(IVISC.EQ.1)THEN
      JEND=JL1
      ELSE
      JEND=JL
      ENDIF
      IF(ISUP.EQ.3)THEN
      IBEG=2
      ELSE
      IBEG=1
      ENDIF
      DO 20 I=IBEG,IL
      DO 20 J=2,JEND
      DO 20 K=1,4
      QQ=Q(I,J,K)
C     IF(QQ.EQ.0.D0)GO TO 20
      SS1(K)=SS1(K)+(DQ(I,J,K)*RJ(I,J)/Y(I,J))**2
      SS2(K)=SS2(K)+QQ**2
  20  CONTINUE
      DO 30 K=1,4
  30  SS(K)=DSQRT(SS1(K)/SS2(K))
      WRITE(19,500)NADV,(SS(K),K=1,4)
 500  FORMAT(I5,3X,4(1X,E14.7))
      RETURN
```

```
      ENTRY MASS
      PI=DACOS(-1.D0)
      DO 80 I=1,IL
      FLRT=0.
      DO 75 J=1,JL1
      DELR=DSQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
      CXCY=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCY1=DSQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
      FLRT=FLRT+0.5*PPI*(Y(I,J+1)+Y(I,J))*DELR
     >     *(RHO(I,J+1)*UN(I,J+1)/CXCY1+RHO(I,J)*UN(I,J)/CXCY)
   75 CONTINUE
      WRITE(22,789)I,FLRT
   80 CONTINUE
  789 FORMAT(1X,I8,E14.7)
      RETURN
      ENTRY OUTPUT
      WRITE(22,550)NADV
  550 FORMAT(//10(1H*)/'   NADV=',I5//)
      DO 50 I=1,IL
      DO 50 J=1,JL
      ST=(E(I,J)/RHO(I,J)-GM1(I,J)*0.5/GAMMA(I,J)*(U(I,J)**2+
     >   V(I,J)**2))/CV(I,J)
      TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
      RMA=DSQRT((U(I,J)*U(I,J)+V(I,J)*V(I,J))/GAMMA(I,J)
     >*RHO(I,J)/P(I,J))
      SP=P(I,J)*(ST/TT)**(GAMMA(I,J)/GM1(I,J))
      WRITE(18,607)X(I,J),Y(I,J),P(I,J),RMA,TT,SP
      WRITE(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
  607 FORMAT(6(1X,E14.7))
C     WRITE(6,600)I,J,RHO(I,J),U(I,J),V(I,J),E(I,J),ST
C     WRITE(6,650)P(I,J),UN(I,J),VN(I,J),SP,TT
  600 FORMAT(1X,'#',I2,',',I2,3X,5(1X,E10.3))
  650 FORMAT(10X,5(1X,E10.3))
   50 CONTINUE
C
C  WRITE THE LAST TWO LINES
C
      DO 55 I=116,117
      DO 55 J=1,JL
   55 WRITE(68) (Q(I,J,K),K=1,4)
C
      RETURN
      END
C*****************************************************************
C*
C*  LIBRARY SUBROUTINES
C*
      SUBROUTINE EEL(J,MM,JMAX,E,EL,AM,BM,CM,DM,IN,AL,BE)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION IN(MM),E(MM,MM,JMAX),EL(MM,JMAX)
      DIMENSION AM(MM,MM),BM(MM,MM),CM(MM,MM),DM(MM)
      DIMENSION AL(MM,MM),BE(MM)
      DO 30 M=1,MM
      TP=0.0D0
      DO 20 N=1,MM
```

```
      T1=0.0D0
      IF(J.EQ.1)GO TO 10
      TP=TP+AM(M,N)*EL(N,J-1)
      DO 5 K=1.MM
    5 T1=T1+AM(M,K)*E(K,N,J-1)
   10 CONTINUE
      AL(M,N)=BM(M,N)-T1
   20 CONTINUE
      EL(M,J)=DM(M)+TP
   30 CONTINUE
      DO 50 M=1,MM
      DO 40 N=1,MM
   40 E(M,N,J)=CM(M,N)
   50 CONTINUE
      CALL AXB(MM,MM,AL,E(1,1,J),BE,0,IN)
      CALL AXB(MM,1,AL,EL(1,J),BE,1,IN)
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE SOLU(W,JMAX,MM,E,EL)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION W(MM,JMAX),E(MM,MM,JMAX),EL(MM,JMAX)
      DO 40 M=1,MM
      W(M,JMAX)=EL(M,JMAX)
   40 CONTINUE
      DO 50 J1=2,JMAX
      J=JMAX+1-J1
      DO 46 M=1,MM
      SUM=0.0D0
      DO 44 K=1,MM
      SUM=SUM+E(M,K,J)*W(K,J+1)
   44 CONTINUE
      W(M,J)=SUM+EL(M,J)
   46 CONTINUE
   50 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE AXB(N,M,A,B,X,INIT,IPS)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(N,N),B(N,M),IPS(N),X(N)
      IF(INIT.EQ.0)CALL DECOMP(N,A,IPS)
      DO 10 I=1,M
      CALL SOLV(N,A,B(1,I),X,IPS)
   10 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE DECOMP(N,UL,IPS)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION UL(N,N),IPS(N)
      DO 5 I=1,N
      IPS(I)=I
    5 CONTINUE
      NM1=N-1
```

```
      DO 17 K=1,NM1
      IF (K.EQ.0)GO TO
      DO 11 I=K,N
      IP=IPS(I)
      SIZE=DABS(UL(IP,K))
      IF((SIZE-BIG)11,11,10
   10 BIG=SIZE
      IDXPIV=I
   11 CONTINUE
      IF(IDXPIV-K)14,15,14
   14 J=IPS(K)
      IPS(K)=IPS(IDXPIV)
      IPS(IDXPIV)=J
   15 KP=IPS(K)
      PIVOT=UL(KP,K)
      KP1=K+1
      DO 16 I=KP1,N
      IP=IPS(I)
      EM=UL(IP,K)/PIVOT
      UL(IP,K)=-EM
      DO 16 J=KP1,N
      UL(IP,J)=UL(IP,J)+EM*UL(KP,J)
   16 CONTINUE
   17 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE SOLV(N,UL,B,X,IPS)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION UL(N,N),B(N),X(N),IPS(N)
      NP1=N+1
      I=IPS(1)
      X(1)=B(IP)
      DO 2 I=2,N
      IP=IPS(I)
      IM1=I-1
      SUM=0.0D0
      DO 1 J=1,IM1
    1 SUM=SUM+UL(IP,J)*X(J)
    2 X(I)=B(IP)-SUM
      IP=IPS(N)
      B(N)=X(N)/UL(IP,N)
      DO 4 IBACK=2,N
      I=NP1-IBACK
      IP=IPS(I)
      IP1=I+1
      SUM=0.0D0
      DO 3 J=IP1,N
    3 SUM=SUM+UL(IP,J)*B(J)
    4 B(I)=(X(I)-SUM)/UL(IP,I)
      RETURN
      END
C-----------------------------------------------------------------
C     SET ZERO FOR MATRIC (M,M)
      SUBROUTINE SZERO(M,A)
```

```
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      A(I,J)=0.0D0
   10 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
C  SCALAR*METRIC (M,M)
      SUBROUTINE SMM(M,C,A,B)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      B(I,J)=C*A(I,J)
   10 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
C  METRIX*METRIX (M*M)
      SUBROUTINE MMM(M,A,B,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M),C(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      C(I,J)=0.0D0
      DO 10 K=1,M
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
   10 CONTINUE
      RETURN
      END
C*
      SUBROUTINE SYH(IL,IU,BB,DD,AA,CC)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION AA(1),BB(1),CC(1),DD(1)
C....
C....SUBROUTINE SYH SOLVES TRIDIAGONAL SYSTEM BY ELIMINATION
C....IL = SUBSCRIPT OF FIRST EQUATION
C....IU = SUBSCRIPT OF LAST EQUATION
C....BB = COEFFICIENT BEHIND DIAGONAL
C....DD = COEFFICIENT ON DIAGONAL
C....AA = COEFFICIENT AHEAD OF DIAGONAL
C....CC = ELEMENT OF CONSTANT VECTOR
C....
C....ESTABLISH UPPER TRIANGULAR MATRIX
C....
      LP = IL+1
      DO 10 I = LP,IU
      R = BB(I)/DD(I-1)
      DD(I) = DD(I)-R*AA(I-1)
  10  CC(I) = CC(I)-R*CC(I-1)
C...
C... BACK SUBSTITUTION
C...
```

```
      CC(IU) = CC(IU)/DD(IU)
      DO 20 I =LP,IU
      J = IU-I+IL
   20 CC(J) = (CC(J)-AA(J)*CC(J+1))/DD(J)
C...
C... SOLUTION STORED IN CC
C...
      RETURN
      END
C*****************************************************************
      SUBROUTINE INVER(M,A,AINV)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION  A(4,4),B(4,4),AINV(4,4),COF(4,4)
      A11=A(1,1)
      A12=A(1,2)
      A13=A(1,3)
      A14=A(1,4)
      A21=A(2,1)
      A22=A(2,2)
      A23=A(2,3)
      A24=A(2,4)
      A31=A(3,1)
      A32=A(3,2)
      A33=A(3,3)
      A34=A(3,4)
      A41=A(4,1)
      A42=A(4,2)
      A43=A(4,3)
      A44=A(4,4)
      DET=A11*(A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
     > -A23*A32*A44-A22*A43*A34)-
     >    A12*(A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
     > -A23*A31*A44-A21*A43*A34)+
     >    A13*(A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
     > -A22*A31*A44-A21*A42*A34)-
     >    A14*(A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
     > -A22*A31*A43-A21*A42*A33)
      COF(1,1)=A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
     > -A23*A32*A44-A22*A43*A34
      COF(1,2)=-(A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
     > -A23*A31*A44-A21*A43*A34)
      COF(1,3)=A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
     > -A22*A31*A44-A21*A42*A34
      COF(1,4)=-(A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
     > -A22*A31*A43-A21*A42*A33)
      COF(2,1)=-(A12*A33*A44+A13*A34*A42+A14*A32*A43-A14*A33*A42
     > -A13*A32*A44-A12*A43*A34)
      COF(2,2)=A11*A33*A44+A13*A34*A41+A14*A31*A43-A14*A33*A41
     > -A13*A31*A44-A11*A43*A34
      COF(2,3)=-(A11*A32*A44+A12*A34*A41+A14*A31*A42-A14*A32*A41
     > -A12*A31*A44-A11*A42*A34)
      COF(2,4)=A11*A32*A43+A12*A33*A41+A13*A31*A42-A13*A32*A41
     > -A12*A31*A43-A11*A42*A33
      COF(3,1)=A12*A23*A44+A13*A24*A42+A14*A22*A43-A14*A23*A42
     > -A13*A22*A44-A12*A43*A24
```

```
      COF(3,2)=-(A11*A23*A44+A13*A24*A41+A14*A21*A43-A14*A23*A41
     > -A13*A21*A44-A11*A43*A24)
      COF(3,3)=A11*A22*A44+A12*A24*A41+A14*A21*A42-A14*A22*A41
     > -A12*A21*A44-A11*A42*A24
      COF(3,4)=-(A11*A22*A43+A12*A23*A41+A13*A21*A42-A13*A22*A41
     > -A12*A21*A43-A11*A42*A23)
      COF(4,1)=-(A12*A23*A34+A13*A24*A32+A14*A22*A33-A14*A23*A32
     > -A13*A22*A34-A12*A33*A24)
      COF(4,2)=A11*A23*A34+A13*A24*A31+A14*A21*A33-A14*A23*A31
     > -A13*A21*A34-A11*A33*A24
      COF(4,3)=-(A11*A22*A34+A12*A24*A31+A14*A21*A32-A14*A22*A31
     > -A12*A21*A34-A11*A32*A24)
      COF(4,4)=A11*A22*A33+A12*A23*A31+A13*A21*A32-A13*A22*A31
     > -A12*A21*A33-A11*A32*A23
      AINV(1,1)=COF(1,1)/DET
      AINV(1,2)=COF(2,1)/DET
      AINV(1,3)=COF(3,1)/DET
      AINV(1,4)=COF(4,1)/DET
      AINV(2,1)=COF(1,2)/DET
      AINV(2,2)=COF(2,2)/DET
      AINV(2,3)=COF(3,2)/DET
      AINV(2,4)=COF(4,2)/DET
      AINV(3,1)=COF(1,3)/DET
      AINV(3,2)=COF(2,3)/DET
      AINV(3,3)=COF(3,3)/DET
      AINV(3,4)=COF(4,3)/DET
      AINV(4,1)=COF(1,4)/DET
      AINV(4,2)=COF(2,4)/DET
      AINV(4,3)=COF(3,4)/DET
      AINV(4,4)=COF(4,4)/DET
C     CALL MMM(4,A,AINV,B)
C     DO 1 MM=1,4
C     WRITE(5,10) (B(MM,NN),NN=1,4)
C   1 CONTINUE
   10 FORMAT(4D16.7)
      RETURN
      END
C*************************************************************
      SUBROUTINE MMV(M,A,B,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M),C(M)
      DO 10 I=1,M
      C(I)=0.DO
      DO 10 K=1,M
      C(I)=C(I)+A(I,K)*B(K)
   10 CONTINUE
      RETURN
      END
C*************************************************************
      SUBROUTINE CPGAM(CP,CV,GAMMA,GM1,R,I,J,
     >  RHO,RHOU,RHOV,E,TCP)
C*************************************************************
      PARAMETER(IZ=150,JZ=100)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
```

```
     >               ,CPA8,CPA9,CPA10,ENE(101)
C=========
      IF(TCP.NE.0.0) GOTO 20
      UU=RHOU/RHO
      VV=RHOV/RHO
      EE=E/RHO-0.5*(UU**2+VV**2)
      TT=300.0
      IF(EE.LE.ENE(1)) GO TO 20
      DO 10 MM=1,101
        EA= EE - ENE(MM)
        EB= EE - ENE(MM+1)
        ESIGN= EA*EB
      IF(ESIGN.LE.0.D0)THEN
        T1=300.0+27.611*DFLOAT(MM-1)
        T2=300.0+27.611*DFLOAT(MM)
        TT=(T2*EA-T1*EB)/(EA-EB)
        GO TO 20
      ELSE
      END IF
 10   CONTINUE
      TT=3061.1D0
 20   CONTINUE
      IF(TCP.NE.0.0) TT=TCP
C*
      IF(TT.LE.1000.0)THEN
        CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
        CV=CP-R
      ELSE
        CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
        CV=CP-R
      END IF
      GAMMA=CP/CV
      GM1=GAMMA-1.0
      RETURN
      END
C***************
      SUBROUTINE CPCOEF
C***************
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
     >               ,CPA8,CPA9,CPA10,ENE(101)
      DIMENSION Y(10),A1(10),A2(10),A3(10),A4(10),A5(10)
     >         ,A6(10),A7(10),A8(10),A9(10),A10(10),WM(10)
      DATA RU,WMMIX/8314.3,20.405/
C====================
C CO
      WM(1)=28.010
      Y(1)= 0.13108
C CO2
      WM(2)=44.0
      Y(2)= 0.03636
C H
      WM(3)=1.0
      Y(3)= 0.02387
C H2
```

```
      WM(4)=2.0
      Y(4)= 0.15802
C H2O
      WM(5)=18.0
      Y(5)= 0.32366
C NO
      WM(6)=30.0
      Y(6)= 0.00260
C N2
      WM(7)=28.0
      Y(7)= 0.30407
C O
      WM(8)=16.0
      Y(8)= 0.00158
C OH
      WM(9)=17.0
      Y(9)= 0.01744
C O2
      WM(10)=32.0
      Y(10)= 0.00129
C---------------------------CO
      A1(1)= 0.29840696E+01
      A2(1)= 0.14891390E-02
      A3(1)=-0.57899684E-06
      A4(1)= 0.10364577E-09
      A5(1)=-0.69353550E-14
C
      A6(1)= 0.37100928E+01
      A7(1)=-0.16190964E-02
      A8(1)= 0.36923594E-05
      A9(1)=-0.20319674E-08
      A10(1)= 0.23953344E-12
C---------------------------CO2
      A1(2)= 0.44608041E+01
      A2(2)= 0.30981719E-02
      A3(2)=-0.12392571E-05
      A4(2)= 0.22741325E-09
      A5(2)=-0.15525954E-13
C
      A6(2)= 0.24007797E+01
      A7(2)= 0.87350957E-02
      A8(2)=-0.66070878E-05
      A9(2)= 0.20021861E-08
      A10(2)= 0.63274039E-15
C---------------------------H
      A1(3)= 0.25000000E+01
      A2(3)= 0.00000000
      A3(3)= 0.00000000
      A4(3)= 0.00000000
      A5(3)= 0.00000000
C
      A6(3)= 0.25000000E+01
      A7(3)= 0.00000000
      A8(3)= 0.00000000
      A9(3)= 0.00000000
```

```
      A10(3)= 0.00000000
C-------------------------H2
      A1(4)= 0.30558123E+01
      A2(4)= 0.59740400E-03
      A3(4)=-0.16747471E-08
      A4(4)=-0.21247544E-10
      A5(4)= 0.25195487E-14
C
      A6(4)= 0.29432327E+01
      A7(4)= 0.34815509E-02
      A8(4)=-0.77713819E-05
      A9(4)= 0.74997496E-08
      A10(4)=-0.25203379E-11
C-------------------------H2O
      A1(5)= 0.26340654E+01
      A2(5)= 0.31121899E-02
      A3(5)=-0.90278449E-06
      A4(5)= 0.12673054E-09
      A5(5)=-0.69164732E-14
C
      A6(5)= 0.41675564E+01
      A7(5)=-0.18106868E-02
      A8(5)= 0.59450878E-05
      A9(5)=-0.48670871E-08
      A10(5)= 0.15284144E-11
C-------------------------NO
      A1(6)= 0.31486543E+01
      A2(6)= 0.14151823E-02
      A3(6)=-0.57574881E-06
      A4(6)= 0.10738529E-09
      A5(6)=-0.73900199E-14
C
      A6(6)= 0.42484931E+01
      A7(6)=-0.48661106E-02
      A8(6)= 0.11634155E-04
      A9(6)=-0.99768494E-08
      A10(6)= 0.30483948E-11
C-------------------------N2
      A1(7)= 0.28536374E+01
      A2(7)= 0.16014368E-02
      A3(7)=-0.62888336E-06
      A4(7)= 0.11428932E-09
      A5(7)=-0.77953822E-14
C
      A6(7)= 0.37034288E+01
      A7(7)=-0.14179405E-02
      A8(7)= 0.28625094E-05
      A9(7)=-0.12018374E-08
      A10(7)=-0.13475522E-13
C-------------------------O
      A1(8)= 0.25342961E+01
      A2(8)=-0.12478170E-04
      A3(8)=-0.12562724E-07
      A4(8)= 0.69029862E-11
      A5(8)=-0.63797095E-15
```

```
C
      A6(8)= 0.30309401E+01
      A7(8)=-0.22525853E-02
      A8(8)= 0.39824540E-05
      A9(8)=-0.32604921E-08
      A10(8)= 0.10152035E-11
C-------------------------OH
      A1(9)= 0.28897814E+01
      A2(9)= 0.10005879E-02
      A3(9)=-0.22048807E-06
      A4(9)= 0.20191288E-10
      A5(9)=-0.39409831E-15
C
      A6(9)= 0.38737300E+01
      A7(9)=-0.13393772E-02
      A8(9)= 0.16348351E-05
      A9(9)=-0.52133639E-09
      A10(9)= 0.41826974E-13
C-------------------------O2
      A1(10)= 0.36122139E+01
      A2(10)= 0.74853166E-03
      A3(10)=-0.19820647E-06
      A4(10)= 0.33749008E-10
      A5(10)=-0.23907374E-14
C
      A6(10)= 0.37837135E+01
      A7(10)=-0.30233634E-02
      A8(10)= 0.99492751E-05
      A9(10)=-0.98189101E-08
      A10(10)= 0.33031825E-11
C================================
      CPA1=0.D0
      CPA2=0.D0
      CPA3=0.D0
      CPA4=0.D0
      CPA5=0.D0
      CPA6=0.D0
      CPA7=0.D0
      CPA8=0.D0
      CPA9=0.D0
      CPA10=0.D0
      DO 10 J=1,10
      CPA1=CPA1+Y(J)*A1(J)*RU/WMMIX
      CPA2=CPA2+Y(J)*A2(J)*RU/WMMIX
      CPA3=CPA3+Y(J)*A3(J)*RU/WMMIX
      CPA4=CPA4+Y(J)*A4(J)*RU/WMMIX
      CPA5=CPA5+Y(J)*A5(J)*RU/WMMIX
      CPA6=CPA6+Y(J)*A6(J)*RU/WMMIX
      CPA7=CPA7+Y(J)*A7(J)*RU/WMMIX
      CPA8=CPA8+Y(J)*A8(J)*RU/WMMIX
      CPA9=CPA9+Y(J)*A9(J)*RU/WMMIX
      CPA10=CPA10+Y(J)*A10(J)*RU/WMMIX
  10  CONTINUE
C...
      R=RU/WMMIX
```

```
FILE: AXI2LN   FOR      A1  VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STAT

      DO 20 MM=1,101
      TT=300.0+27.611*DFLOAT(MM-1)
      IF(TT.LE.1000.0)THEN
        CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
        CV=CP-R
        ENE(MM)=CV*TT
      ELSE
        CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
        CV=CP-R
        ENE(MM)=CV*TT
      END IF
 20   CONTINUE
      RETURN
      END
//DATA.INPUT DD *
 &INPUT IL=125,JL=80,NBEG=1,NEND=30,NITER=30,P0=1.D+06,T0=3061.1D0,
        CFL=5.0, OMEGAX=0.25,OMEGAY=0.25,RM1=0.04, RM2=1.2,ISUP=1,
        AIN=1.0, ATH=0.8, RL=1.3, THETA=1.0,CP0=7152.4853,GAMMA0=1.17,
        ITIME=1,IREAD=1,FST=0.00,TWALL=3512.07,FSTY=0.9,PB=0.,
        IVISC=1,IWALL=0,PRN=0.7,REN=1.D5,TREF=3000.,ZMU0=0.D0,
        PRNT=0.7D0, COND=0.0,
 &END
//DATA.FT38F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.H125M80.VIS,
//      DISP=(OLD,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT66F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.RERUN.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT19F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.DQ.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT18F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.SOLU.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=FB,LRECL=130,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT22F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.MASS.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=FB,LRECL=130,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT68F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.LINE.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
// EXEC PROMPTME
```

X14140

USERID: V19 ORIGIN: PSUVM CREATED: 06/20/89 15:42:50

FILENAME: PNSVIS FOR CLASS: A FORMAT:J

SPOOLID: 7821 RECS: 3011 COPY: 1 DUPLICATE: 1

PRINTED AT: PSUVM ID: $PPCBP01 AT: 06/20/89 15:42:54

```
**************************************************************
*
* THIS FILE WAS SENT BY THE COMMAND:
* PRT3812  PNSVIS FOR A1 ( PPCB1 COPIES 1 ORIENT N FONT 11
*
**************************************************************
```

```
FILE: PNSVIS   FOR      A1  VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STA

//STIXXXXX JOB
/*JP T=500, L=10000
// EXEC PGM=IEFBR14
//*
//D DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
//     DSN=STU.I19500.MYH100.HERMES2.DIF.SOLU.VIS
// EXEC FVCG,PARM.SOURCE='OPT(3)'
//* EXEC FWCG
//SYSIN DD *
C   THIS VERSION USES TRUE JACOBIAN
C*************************************************************
C*     PROGRAM NAME: NOZZLE                                  *
C*     AXISYMMETRIC SUPERSONIC NOZZLE FLOW                   *
C*     IN GENERAL COORDINATE SYSTEM                          *
C*     USING TIME ITERATIVE UW/CD DDADI METHOD               *
C*     WITH THIN-LAYER APPROXIMATED NAVIER-STOKE'S EQ.       *
C*************************************************************
C*
C*  MAIN PROGRAM
C*
C*********************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >          (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*********************************************************************
      CALL INITIA
      DO 10 NADV=NBEG,NEND
      CALL SOLVE
      CALL CHECK
 10   CONTINUE
      CALL MASS
      CALL OUTPUT
      STOP
      END
C*
C* SET UP INITIAL CONDITION
C*
      SUBROUTINE INITIA
C*********************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
```

```
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >              ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************
C*
C*    IF THE DIMENSION IN COMMON BLOCK MUST BE CHANGED
C*    PLEASE CHANGE THE PARAMETER STATEMENT
C*
      DIMENSION SS(3500,4)
      NAMELIST/INPUT/IL,JL,NEND,PO,TO,CFL,OMEGAX,OMEGAY,RM1,AIN,FST,
     > NITER,AEX,RL,THETA,CPO,GAMMAO,NBEG,ITIME,IVISC,NORD,IWALL,RM2
     >   ,IREAD,PRN,REN,TREF,ZMUO,TWALL,FSTY,PB,PRNT,CFL1,IWBC,BIOT,TW1
     >   ,IFLOW
      CALL ERRSET(208,256,-1,0,0,0)
C... IL=TOTAL GRID NUMBER IN XI DIRECTION
C... JL=TOTAL GRID NUMBER IN ETA DIRECTION
C... NBEG= COUNTING INDEX OF ITERATION STEP
C          =1 FOR THE FIRST RUN
C          =ANY NUMBER EXCEPT 1 FOR RERUN
C... NEND= NUMBER OF ITERATIONS FOR THE FIRST RUN ONLY
C... NITER=NUMBER IF ITERATIONS TO BE RUN WHEN RERUN(NBEG.NE.1)
C... PO  = STAGNATION PRESSURE
C... PB=THE BACK PRESSURE AT THE EXIT OF NOZZLE
C      =0.  (SUBSONIC FLOW EXTRAPOLATED FROM INTERIOR)
C      = THE SPECIFIED BACK PRESSURE (FIXED THE PRESSURE FOR
C                    SUBSONIC PORTION AT EXIT)
C... TO  = STAGNATION TEMPERATURE
C... CFL = CFL NUMBER
C... CFL1= CFL NUMBER FOR PNS MARCHING
C... OMEGAX=ARTIFICIAL DISSIPATION CONSTANT IN XI DIRECTION
C... OMEGAY=ARTIFICIAL DISSIPATION CONSTANT INETA DIRECTION
C... IREAD = 0 FOR DEFAULT CONICAL NOZZLE
C            1 READ GRID FROM DATA FILE
C... RM1 =THE INITIAL GUESS FOR INLET MACH NUMBER
C... RM2 =THE INITIAL GUESS FOR EXIT MACH NUMBER
C... AIN =THE INLET RADIUS FOR CONICAL NOZZLE (IGNORED IN IREAD=1)
C... AEX =THE EXIT RADIUS FOR CONICAL NOZZLE (IGNORED IF IREAD=1)
C... RL =TOTAL LENGTH OF CONICAL NOZZLE (IGNORED IF OREAD=1)
C... ITIME= 0 FOR CONSTANT DT   1 FOR CONSTANT CFL
C... IVISC= 0  INVISCID FLOW
C           1  VISCOUS FLOW
C... NORD = 0 FOR FIRST ORDER UPWIND IN XI
C           1 FOR SECOND ORDER UPWIND IN XI
C... FST = STRETCHING FACTOR IN XI DIRECTIO (0 FOR UNIFORM GRID)
C... FSTY= STRETCHING FACTOR IN ETA DIRECTION (0 FOR UNIFORM GRID)
```

```
                                  SMESP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STA
                                  SPECIFIC HEAT
                                  NUMBER
                                  FLOW
                                  FLOW
                                  OR OFF IN THIS SUBROUTINE)
                                  WALL
                                  WALL TEMPERATURE
                                  OF COOLING LIQUID
                                  TUBE INLET (M. CP/2 PI K YIN)
                                  FLOW FROM INLET TO EXIT
                                  FLOW FROM EXIT TO INLET
C                                 ONLY VALID FOR IFLOW=-1
C... TWA = WALL TEMPERATURE FOR IWALL=1
C... TREF = REFERENCE TEMPERATURE FOR VISCOSITY CALCULATION
C... ZMUO = THE VISCOSITY AT T=TREF
C... IWBC = 0 FOR EXPLICIT WALL B. C.
C           1 FOR IMPLICIT WALL B. C.
C ** READ INPUT DATA
      READ(5,INPUT)
      WRITE(12,INPUT)
C ** SET UP GEOMETRY
      IL1=IL-1
      JL1=JL-1
C
      CALL GRID
C
      PI=DACOS(-1.DO)
C  TURN OF ADVERSE COOLING FLOW
      IF(NBEG.EQ.1) IFLOW=1
C
      DO 10 I=1,IL
      AREA(I)=AIN+(AEX-AIN)*DFLOAT(I-1)/DFLOAT(IL1)
   10 CONTINUE
      DO 20 I=1,IL
      DO 20 J=1,JL
      X(I,J)=DFLOAT(I-1)/DFLOAT(IL1)*RL
   20 Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
      IF(FST.NE.0.DO)THEN
      DO=(FST-1.0)/(FST**IL1-1.)*RL
      DO 15 I=1,IL
      XL=DO*(FST**(I-1)-1.)/(FST-1.)
      AREA(I)=AIN+XL/RL*(AEX-AIN)
      DO 15 J=1,JL
      X(I,J)=XL
      Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
   15 CONTINUE
      ELSE
      ENDIF
C* STRETCH THE GRID ALONG Y-DIRECETION IN VISCOUS CASE
      IF(FSTY.NE.0.DO)THEN
        DO 17 I=1,IL
```

```
          Y(I,1)=0.
          DAO=(1.-FSTY)/(1.-FSTY**JL1)*AREA(I)
        DO 17 J=2,JL
          Y(I,J)=Y(I,J-1)+DAO*FSTY**(J-2)
  17    CONTINUE
      ELSE
      ENDIF
C * READ GRID FROM DATA FILE
      IF(IREAD.EQ.1)THEN
      DO 25 I=1,IL
      DO 25 J=1,JL
      READ(38)III,JJJ,X(I,J),Y(I,J)
  25  CONTINUE
      ELSE
      END IF
C ** COORDINATE TRANSFORMATION
      EXI=1.0
      EYI=1.0
      DO 30 I=1,IL
      IP1=I
      IM1=I-1
      IF(I.EQ.1)IM1=1
      IF(I.EQ.1)IP1=2
      DSAI=2.*EXI
      IF(I.EQ.1.OR.I.EQ.IL)DSAI=EXI
      DO 30 J=1,JL
      JP1=J+1
      JM1=J-1
      IF(J.EQ.1)JM1=1
      IF(J.EQ.JL)JP1=JL
      DETA=2.*EYI
      IF(J.EQ.1.OR.J.EQ.JL)DETA=EYI
      XSAI=(X(IP1,J)-X(IM1,J))
      YSAI=(Y(IP1,J)-Y(IM1,J))
      XETA=(X(I,JP1)-X(I,JM1))/DETA
      YETA=(Y(I,JP1)-Y(I,JM1))/DETA
      IF(I.GT.2.AND.I.LT.IL1)THEN
       XSAI=XSAI+NORD*0.5*(X(I,J)-2.*X(I-1,J)+X(I-2,J))
       YSAI=YSAI+NORD*0.5*(Y(I,J)-2.*Y(I-1,J)+Y(I-2,J))
      ENDIF
       IF(J.EQ.1)THEN
        XETA=XETA-0.5*(X(I,J)-2.*X(I,J+1)+X(I,J+2))
        YETA=YETA-0.5*(Y(I,J)-2.*Y(I,J+1)+Y(I,J+2))
       ELSE
       ENDIF
C
      IF(J.EQ.JL) THEN
      XETA=(3.D0*X(I,JL)-4.D0*X(I,JL-1)+X(I,JL-2))*0.5D0
      YETA=(3.D0*Y(I,JL)-4.D0*Y(I,JL-1)+Y(I,JL-2))*0.5D0
      ELSE
      ENDIF
C
      RJP=XSAI*YETA-XETA*YSAI
      RJ(I,J)=1./RJP
      SAIX(I,J)=YETA/RJP
```

```
      SAIY(I,J)=-XETA/RJP
      ETAX(I,J)=-YSAI/RJP
 30   ETAY(I,J)=XSAI/RJP
C ** INITIALIZATION
      RGAS=8314.3/20.405
      R=RGAS
      DO 991 I=1,IL
      DO 991 J=1,JL
      TTT=3061.1D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TTT)
 991  CONTINUE
C     GM10=GAMMA0-1.
C     R=CP0*GM10/GAMMA0
C     CV0=CP0/GAMMA0
C
C*
C* GIVE THE INITIAL VALUE OF VISCOSTY
C*    IF THE VISCOSITY AT T=TREF IS GIVEN FROM INPUT
C*    THE CALCULATION FOR ZMU0 MUST BE SWITCHED OFF
C*
C     TIN=T0/(1.+0.5*GM10*RM1**2)
C     UIN=RM1*DSQRT(GAMMA0*R*TIN)
C     PIN=P0*(TIN/T0)**(GAMMA0/GM10)
C     RIN=PIN/(R*TIN)
      BIOT=BIOT*Y(1,JL)
C      ZMU0=(RIN*UIN*AREA(1)*2.)/REN
C* CALCULATE METRIC TERMS AT MID POINTS
C*
      CALL MCONST
C ** SKIP TO RERUN THE CODE
      IF(NBEG.NE.1)GOTO 300
C ** READ IN THE STARTING LINES
      DO 60 I=1,2
      DO 60 J=1,JL
      READ(68) (Q(I,J,K),K=1,4)
      TCP=0.D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
 50   CONTINUE
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J) =GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
 60   CONTINUE
C     REWIND 68
C
      RETURN
 300  CONTINUE
 310  READ(19,720,END=1000)NDUM,(SS(NDUM,K),K=1,4)
      GOTO 310
1000  CONTINUE
      REWIND 19
      NBEG=NDUM+1
```

```
      NEND=NBEG+NITER-1
      DO 320 N=1,NDUM
 320  WRITE(19,720)N,(SS(N,K),K=1,4)
 720  FORMAT(I5,3X,4(1X,E14.7))
      DO 330 I=1,IL
      DO 330 J=1,JL
      READ(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
      TCP=0.DO
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J) =GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CY=DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*CO)/EXI
      CY=(VN(I,J)+CY*CO)/EYI
      EIGNN=DABS(CX)
      IF(EIGNN.LE.DABS(CY))EIGNN=DABS(CY)
      DELTAU(I,J)=CFL/EIGNN
 330  CONTINUE
      REWIND 66
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE SOLVE
C*
C*   SOLVE SUBROUTINE
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
C*
C*    STRAT THE CODE BY PNS A PLUS MARCHING
C*
      IF(NADV.NE.1)GOTO 5
       CALL PNS
```

```
       RETURN
5      CONTINUE
C*
       CALL FLUX(1)
       CALL FLUX(2)
       IF(IVISC.EQ.1)THEN
        CALL MULAM(1)
        CALL MULAM(2)
       ENDIF
       DO 40 I=3,IL
C*
C*     THIS DO LOOP CONTROLS THE LOCAL ITERATION FOR
C*     EACH CONSTANT XI LINE
C*
       DO 35 LOCAL=1,1
       CALL RHS(I)
       IF(IVISC.EQ.1) THEN
        CALL MULAM(I)
        IF(PRNT.NE.0.D0) CALL MUTUR(I)
       ENDIF
       IF(IVISC.EQ.1)CALL VRHS(I)
C*   CALCULATE RESIDUAL
       DO 10 J=1,JL
       DO 10 K=1,4
 10    DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
C*
C*   ADD ETA-DIRECTION 4TH ORDER ARITFICIAL VISCOSITY
C*
       IF(OMEGAY.NE.0.D0)CALL ADDY(I)
C*
C*   SOLVE L-ETA OPERATOR
C*
       CALL COEFY(I)
C*
C*    UPDATE VARIABLES AFTER X-SWEEP
C*
C       JEND=JL
C       IF(IVISC.EQ.1)JEND=JL1
       DO 20 J=2,JL
       RJJ=RJ(I,J)/Y(I,J)
       DO 15 K=1,4
 15    Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
       TCP=0.D0
       CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
      > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
       U(I,J)=RHOU(I,J)/RHO(I,J)
       V(I,J)=RHOV(I,J)/RHO(I,J)
       UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
       VN(I,J)=U(I,J)*ETAX(I,J)+ETAY(I,J)*V(I,J)
       P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
 20    CONTINUE
       CALL CLBC(I)
       IF(IVISC.EQ.1.AND.IWBC.EQ.0)CALL WALLBC(I)
 35    CONTINUE
 40    CONTINUE
```

```
C*
C*  BACKWARD SWEEPI
C*
      DO 90 IB=2,IL-2
      I=IL-IB+1
      DO 86 LOCAL=1,1
      CALL RHS(I)
      IF(IVISC.EQ.1) THEN
       CALL MULAM(I)
       IF(PRNT.NE.0.D0) CALL MUTUR(I)
      ENDIF
      IF(IVISC.EQ.1)CALL VRHS(I)
      DO 50 J=1,JL
      DO 50 K=1,4
  50  DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
      IF(OMEGAY.NE.0.D0)CALL ADDY(I)
      CALL COEFY(I)
C*
C*  UPDATING VARIABLES
C*
      DO 70 J=2,JL
      RJJ=RJ(I,J)/Y(I,J)
      DO 60 K=1,4
 60   Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
      TCP=0.D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
      C0=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CY=DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*C0)
      CY=(VN(I,J)+CY*C0)
      EIGNN=DABS(CX)
      IF(EIGNN.LE.DABS(CY))EIGNN=DABS(CY)
      DELTAU(I,J)=ITIME*CFL/EIGNN+(1-ITIME)*DELTAU(I,J)
 70   CONTINUE
C *
C * CENTERLINE BOUNDARY CONDITIONS
      CALL CLBC(I)
      IF(IVISC.EQ.1.AND.IWBC.EQ.0)CALL WALLBC(I)
  86  CONTINUE
  90  CONTINUE
      RETURN
      END
C*
C*   THIS SUBROUTINE SOLVE THE FLOW FIELD BY
C*    MARCHING IN XI DIRECTION
C*
      SUBROUTINE PNS
C*****************************************************************
```

```
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >             ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************
      DIMENSION SS(4)
      DATA INNER/200/
C **  FORWARD SWEEP
      WRITE(19,*) ' ****  PNS MARCHING BEGINS  ****'
      IF(IVISC.EQ.1) CALL MULAM(1)
      IF(IVISC.EQ.1) CALL MULAM(2)
      CALL FLUX(1)
      CALL FLUX(2)
      DO 999 I=3,IL
      WRITE(19,*) ' ### I=',I
C*
C* GIVE THE INITIAL GUESS FROM PREVIOUS LINE
C*
      DO 17 J=1,JL
C      DELTAU(I,J)=DELTAU(I-1,J)
      DO 16 K=1,4
 16   Q(I,J,K)=Q(I-1,J,K)
      TCP=0.D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      RHO(I,J)=RHO(I-1,J)
      U(I,J)=U(I-1,J)
      V(I,J)=V(I-1,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      IF(J.EQ.JL) VN(I,J)=0.D0
       IF(J.EQ.JL)V(I,J)=-U(I,J)*ETAX(I,J)/ETAY(I,J)
      IF(J.EQ.JL) Q(I,J,2)=RHO(I,J)*U(I,J)
      IF(J.EQ.JL) Q(I,J,3)=RHO(I,J)*V(I,J)
      P(I,J)=P(I-1,J)
 17   CONTINUE
C      IF(I.EQ.2) THEN
      DO 19 J=1,JL
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CY=VN(I,J)+DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)*CO
      CX=UN(I,J)+DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)*CO
      DELTAU(I,J)=CFL1/DABS(CY)
C       DELTAU(I,J)=CFL1/DABS(CX)
```

```
  19   CONTINUE
C      ENDIF
C*
      DO 998 ICOUNT=1,INNER
C*  RHS CALCULATION
      CALL RHS(I)
      IF(IVISC.EQ.1) CALL MULAM(I)
      IF(PRNT.NE.0.D0) CALL MUTUR(I)
      IF(IVISC.EQ.1) CALL VRHS(I)
      DO 40 J=1,JL
      DO 40 K=1,4
 40   DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
C*
C* ADD ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C*
      IF(OMEGAY.NE.0.0D0)CALL ADDY(I)
C*
C* SOLVE LETA-OPERATOR
C*
      CALL COEFY(I)
C*
C* UPDATING VARIABLES
C*
      DO 70 J=2,JL
      RJJ=RJ(I,J)/Y(I,J)
      DO 60 K=1,4
 60   Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
      TCP=0.D0
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
     > RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
      C0=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CX=DSQRT(SAIX(I,J)*SAIX(I,J)+SAIY(I,J)*SAIY(I,J))
      CY=DSQRT(ETAX(I,J)*ETAX(I,J)+ETAY(I,J)*ETAY(I,J))
      CX=(UN(I,J)+CX*C0)/EXI
      CY=(VN(I,J)+CY*C0)/EYI
      EIGNN=DABS(CY)
      DELTAU(I,J)=ITIME*CFL1/EIGNN+(1-ITIME)*DELTAU(I,J)
 70   CONTINUE
C*
C* EXTRAPOLATE FROM FIELD POINT TO CENTER LINE
C*
      CALL CLBC(I)
      IF(IVSC.EQ.1.AND.IWBC.EQ.0)CALL WALLBC(I)
C*
C*    CALCULATE THE ERROR
C*
      DO 110 K=1,4
 110  SS(K)=0.
      DO 120 J=1,JL
      DO 120 K=1,4
```

```
      QQ=Q(I,J,K)
      IF(QQ.EQ.0.DO.OR.Y(I,J).EQ.0.DO)GO TO 120
      SS(K)=SS(K)+(DQ(I,J,K)/(QQ*Y(I,J)/RJ(I,J)))**2
 120  CONTINUE
      QSUM=0.
      DO 130 K=1,4
      QSUM=QSUM+DSQRT(SS(K))
 130  SS(K)=DSQRT(SS(K))/(IL*JL)
      QSUM=QSUM/4./(IL*JL)
      IF(QSUM.LE.1.D-13) GOTO 995
      WRITE(19,500)ICOUNT,(SS(K),K=1,4)
 500  FORMAT(I5,3X,4(1X,E14.7))
 998  CONTINUE
  995 CONTINUE
      WRITE(19,510) (SS(K),K=1,4)
 510  FORMAT('  &&&  ',4(1X,E14.7))
 999  CONTINUE
      WRITE(19,*) ' ****  PNS MARCHING ENDS   *****'
      CALL MASS
      RETURN
      END
C*
C* SUBROUTINE FOR CALCULATING METRIC TERMS
C* AT THE MIDPOINT
      SUBROUTINE MCONST
C*************************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************************
      DATA FD3,OD3/1.333333333333,0.333333333333/
      DO 20 I=2,IL
      DO 20 J=1,JL1
      IF(I.EQ.IL)THEN
      XSAI=0.5*(X(I,J)+X(I,J+1)-X(I-1,J)-X(I-1,J+1))
      YSAI=0.5*(Y(I,J)+Y(I,J+1)-Y(I-1,J)-Y(I-1,J+1))
      ELSE
      YSAI=0.25*(Y(I+1,J+1)+Y(I+1,J)-Y(I-1,J+1)-Y(I-1,J))
      XSAI=0.25*(X(I+1,J+1)+X(I+1,J)-X(I-1,J+1)-X(I-1,J))
      END IF
      YETA=Y(I,J+1)-Y(I,J)
      XETA=X(I,J+1)-X(I,J)
```

```
      RJJ=1./(XSAI*YETA-XETA*YSAI)
      A1(I,J)=RJJ*(FD3*YSAI**2+XSAI**2)
      A2(I,J)=-RJJ*OD3*XSAI*YSAI
      A3(I,J)=RJJ*(YSAI**2+FD3*XSAI**2)
      A4(I,J)=RJJ*(XSAI**2+YSAI**2)
   20 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE SMOOTH
C*
C*  ADD ARTIFICIAL DISSIPATIONAL TERM FOR SAI,ETA-DIRECTION
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >          (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION ADD(4)
C ** SAI-DIRECTION
      ENTRY ADDX
      COEF=0.125D0*OMEGAX
      DO 70 J=1,JL
      DO 70 I=1,IL
      IF(I.EQ.1) GO TO 10
      IF(I.EQ.2) GO TO 20
      IF(I.EQ.IL1) GO TO 30
      IF(I.EQ.IL) GO TO 40
      DO 5 K=1,4
    5 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >       +6.*Q(I,J,K)-4.*Q(I-1,J,K)
     >       +Q(I-2,J,K))
      GO TO 50
   10 DO 15 K=1,4
      QM=2.*Q(1,J,K)-Q(2,J,K)
      QMM=2.*QM-Q(1,J,K)
   15 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >       +6.*Q(I,J,K)-4.*QM+QMM)
      GO TO 50
   20 DO 25 K=1,4
      QMM=2.*Q(1,J,K)-Q(2,J,K)
   25 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
```

```
     >        +6.*Q(I,J,K)-4.*Q(I-1,J,K)
     >        +QMM)
      GO TO 50
 30   DO 35 K=1,4
      QPP=2.*Q(I+1,J,K)-Q(I,J,K)
 35   ADD(K)=COEF*(QPP-4.*Q(I+1,J,K)+6.*Q(I,J,K)
     >        -4.*Q(I-1,J,K)+Q(I-2,J,K)
     >        )
      GO TO 50
 40   DO 45 K=1,4
      QP=2.*Q(I,J,K)-Q(I-1,J,K)
      QPP=2.*QP-Q(I,J,K)
 45   ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
     >       Q(I-1,J,K)+Q(I-2,J,K))
 50   CONTINUE
      DO 60 K=1,4
 60   DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
 70   CONTINUE
      RETURN
C **
C   ADD ETA-DLRECTLON 4TH ORDER ARTLFLCLAL VLSCOSLTY
C **
      ENTRY ADDY(II)
      I=II
      COEF=0.125D0*OMEGAY
      DO 170 J=1,JL
      IF(J.EQ.1) GO TO 110
      IF(J.EQ.2) GO TO 120
      IF(J.EQ.JL1) GO TO 130
      IF(J.EQ.JL) GO TO 140
      DO 95 K=1,4
 95   ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >     +6.*Q(I,J,K)-4.*Q(I,J-1,K)
     >     +Q(I,J-2,K))
      GO TO 150
 110  DO 115 K=1,4
      QM=2.*Q(I,1,K)-Q(I,2,K)
      QMM=2.*QM-Q(I,1,K)
 115  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >     +6.*Q(I,J,K)-4.*QM+QMM)
      GO TO 150
 120  DO 125 K=1,4
      QMM=2.*Q(I,1,K)-Q(I,2,K)
 125  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >  +6.*Q(I,J,K)-4.*Q(I,J-1,K)
     >   +QMM)
      GO TO 150
 130  DO 135 K=1,4
      QPP=2.*Q(I,J+1,K)-Q(I,J,K)
 135  ADD(K)=COEF*(QPP-4.*Q(I,J+1,K)+6.*Q(I,J,K)
     >  -4.*Q(I,J-1,K)+Q(I,J-2,K)
     >  )
      GO TO 150
 140  DO 145 K=1,4
      QP=2.*Q(I,J,K)-Q(I,J-1,K)
```

```
      QPP=2.*QP-Q(I,J,K)
 145  ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
     >  Q(I,J-1,K)+Q(I,J-2,K))
 150  CONTINUE
      DO 160 K=1,4
160   DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
170   CONTINUE
      RETURN
      END
C
C **  SUBROUTINE FOR CENTER LINE BOUNDARY CONDITIONS
      SUBROUTINE BC
C-------------------------------------------------------------------
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >              ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*******************************************************************
      DATA SCONST/196./
      ENTRY CLBC(II)
      I=II
C *  THE QUANTITIES EXTRAPOLATED ARE U,P,T AND LET V=0
C
      SY=SAIY(I,1)
      EY=ETAY(I,1)
      DENOM=SY-1.5*EY
      IF(I.NE.2.AND.I.LT.IL1)DENOM=DENOM+0.5*NORD*SY
      IF(I.EQ.1)THEN
      UIM1=0.
      PIM1=0.
      RIM1=1.0
      ELSE
      UIM1=U(I-1,1)
      PIM1=P(I-1,1)
      RIM1=RHO(I-1,1)
      END IF
      V(I,1)=0.
      U(I,1)=(SY*UIM1-0.5*EY*(4.*U(I,2)-U(I,3)))/DENOM
      IF(I.NE.2.AND.I.LT.IL1) U(I,1)=U(I,1)+NORD*SY*(U(I-1,1)-
     *   0.5*U(I-2,1))/DENOM
      UN(I,1)=SAIX(I,1)*U(I,1)
      VN(I,1)=ETAX(I,1)*U(I,1)
      P(I,1)=(SY*PIM1-0.5*EY*(4.*P(I,2)-P(I,3)))/DENOM
```

```
      IF(I.NE.2.AND.I.LT.IL1) P(I,1)=P(I,1)+NORD*SY*(P(I-1,1)-
     *   0.5*P(I-2,1))/DENOM
      RIV=1./RGAS
      TIM1=TIM1/RIM1*RIV
      T2=P(I,2)/RHO(I,2)*RIV
      T3=P(I,3)/RHO(I,3)*RIV
      T1=(SY*TIM1-0.5*EY*(4.*T2-T3))/DENOM
      IF(I.NE.2.AND.I.LT.IL1)THEN
       TIM2=P(I-2,1)/RHO(I-2,1)*RIV
       T1=T1+NORD*SY*(TIM1-0.5*TIM2)/DENOM
      ENDIF
      CALL CPGAM(CP(I,1),CV(I,1),GAMMA(I,1),GM1(I,1),RGAS,I,1,
     > RHO(I,1),RHOU(I,1),RHOV(I,1),E(I,1),T1)
      RHO(I,1)=P(I,1)/T1*RIV
      RHOU(I,1)=RHO(I,1)*U(I,1)
      RHOV(I,1)=RHO(I,1)*V(I,1)
      E(I,1)=P(I,1)/GM1(I,1)+0.5*RHO(I,1)*(U(I,1)**2+V(I,1)**2)
      RETURN
C*
      ENTRY WALLBC(II)
      I=II
      J=JL
      CC1=ETAX(I,J)*SAIX(I,J)+ETAY(I,J)*SAIY(I,J)
      CC2=ETAX(I,J)**2+ETAY(I,J)**2
      IF(I.NE.IL)THEN
      AM=-0.5*CC1
      BM=1.5*CC2
      CM=0.5*CC1
      DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
      ELSE
      AM=-CC1
      BM=CC1+1.5*CC2
      CM=0.
      DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
      END IF
      IP1=I+1
      IF(I.EQ.IL)IP1=IL
      PSOL=(DM-AM*P(I-1,J)-CM*P(IP1,J))/BM
      IF(I.EQ.IL.AND.PB.NE.0.D0)PSOL=PB
      RIV=1./RGAS
      IF(IWALL.EQ.0)THEN
        T1=P(I,J-1)*RIV/RHO(I,J-1)
        T2=P(I,J-2)*RIV/RHO(I,J-2)
        DM=CC2*(2.*T1-0.5*T2)
        TIM1=P(I-1,J)*RIV/RHO(I-1,J)
        TIP1=P(IP1,J)*RIV/RHO(IP1,J)
        TSOL=(DM-AM*TIM1-CM*TIP1)/BM
      ELSE
      ENDIF
      IF(IWALL.EQ.0)THEN
       TT=TSOL
      ELSE
       TT=TWALL
      ENDIF
      PP=PSOL
```

```
      U(I,JL)=0.
      V(I,JL)=0.
      RHOU(I,JL)=0.
      RHOV(I,JL)=0.
      RHOO=PP*RIV/TT
      RHO(I,JL)=RHOO
      CALL CPGAM(CP(I,JL),CV(I,JL),GAMMA(I,JL),GM1(I,JL),RGAS,I,JL,
     > RHO(I,JL),RHOU(I,JL),RHOV(I,JL),E(I,JL),TT)
      E(I,JL)  =PP/GM1(I,JL)
      P(I,JL)=PP
      UN(I,JL)=0.
      VN(I,JL)=0.
      RETURN
C*
C*  LAMINAR VISCOSITY CALCULATION
C*
C     ENTRY MULAM(II)
C     I=II
C*  USE SUTHERLAND LAW
C     DO 60 J=1,JL
C     TOS=TREF+SCONST
C     TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
C     TTS=TT+SCONST
C     ZMU(I,J)=ZMUO*TOS/TTS*(TT/TREF)**1.5
C      ZMU(I,J)=ZMUO
C      ZMU(I,J)=ZMUO*(TT/TREF)**0.67
C 60  CONTINUE
C     RETURN
      END
C*************************************************************
      SUBROUTINE MULAM(NN)
C*************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************
      B1=4.3222557667160623D-06
      B2=3.8885996244952953D-08
      B3=-3.7263546610032919D-12
C     DO 50 NN=1,IL
      DO 50 MM=1,JL
      TT=(E(NN,MM)/RHO(NN,MM)-0.5*(U(NN,MM)**2+V(NN,MM)**2))/CV(NN,MM)
```

```
      ZMU(NN,MM)=B1+B2*TT+B3*TT*TT
 50   CONTINUE
        RETURN
        END
C
C     BOLDWIN & LOMAX TURBULENCE MODEL
C
      SUBROUTINE MUTUR(II)
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >          (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION YVERT(JZ),ZMUI(JZ)
      DATA AP,CCP,CKLEB,CWK,VKCON,XK/26., 1.6, .3, .25, .4, .0168/
      DATA ZMUI/JZ*0.0/
      I=II
      FYMAX  = 0.0
      YMAX   = 0.0
      UDIF=0.
      YVERT(JL) = 0.0
      TAUW = ZMU(I,JL)*DABS(ETAY(I,JL)*(U(I,JL)-U(I,JL-1))-
     >                      ETAX(I,JL)*(V(I,JL)-V(I,JL-1)))
      CYP  = DSQRT(RHO(I,JL)*TAUW)/ZMU(I,JL)
C
      DO 10 KK = 2,JL1
      K = JL+1-KK
      YVER  = YVERT(K+1) + 1.0/DSQRT(ETAX(I,K)**2 + ETAY(I,K)**2)
      OMG   = DABS( ETAY(I,K)*(U(I,K+1)-U(I,K-1))*.5
     >             +SAIY(I,K)*(U(I,K)  -U(I-1,K))
     >             -ETAX(I,K)*(V(I,K+1)-V(I,K-1))*.5
     >             -SAIX(I,K)*(V(I,K)  -V(I-1,K))    )
      YPLUS = CYP*YVER
      TURLEN  = VKCON*YVER*(1.0D0 -DEXP(-YPLUS/AP))
      ZMUI(K) = RHO(I,K)*OMG*TURLEN**2
      FY    = TURLEN/VKCON*OMG
      UTOTAL= DSQRT(U(I,K)**2+V(I,K)**2)
      IF(UTOTAL.GE.UDIF) UDIF=UTOTAL
      IF(FY .LT. FYMAX)  GO TO 10
      FYMAX  = FY
      YMAX   = YVER
10    YVERT(K) = YVER
```

```
C
      VXDIF = UDIF
      FWAKE1=YMAX*FYMAX
      FWAKE2=CWK*YMAX*VXDIF**2/FYMAX
      FWAKE =DMIN1(FWAKE1,FWAKE2)
C
      DO 20 KK = 2, JL1
      K = JL+1-KK
      FKLEB     = (CKLEB*YVERT(K)/YMAX)**6
      FKLEB     = 1./(1.0 + 5.5*FKLEB)
      ZMUO      = XK*CCP*RHO(I,K)*FWAKE*FKLEB
      IF(ZMUI(K).GT.ZMUO) THEN
      ZMUTUR = ZMUO
      ELSE
      ZMUTUR = ZMUI(K)
      END IF
      ZMUT(K)= ZMUTUR
      ZMU(I,K)    = ZMU(I,K) + ZMUTUR
C      WRITE(77,119)K,Y(I,K),YVERT(K),U(I,K),ZMUI(K),ZMUO,ZMU(I,K)
C119   FORMAT(2X,I3,6(2X,D13.6))
20    CONTINUE
C
      ZMUT(1)=0.
      ZMUT(JL)=0.
      RETURN
      END
C* SUORCE TERM JACOBIAN MATRIX
      SUBROUTINE DHDQ(D,I,J)
C-----------------------------------------------------------------------
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C**********************************************************************
      DIMENSION D(4,4)
      CALL SZERO(4,D)
      IF(IVISC.EQ.0)THEN
      R2MY=0.
      ELSE
      R2MY=4./3.*ZMU(I,J)/(Y(I,J)*Y(I,J)*RHO(I,J))
      END IF
      D(3,1)=.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/Y(I,J)+IVISC*V(I,J)*R2MY
      D(3,2)=-GM1(I,J)*U(I,J)/Y(I,J)
```

```
      D(3,3)=-GM1(I,J)*V(I,J)/Y(I,J)-IVISC*R2MY
      D(3,4)=GM1(I,J)/Y(I,J)
      RETURN
      END
      SUBROUTINE JACCAL
C*
C*  SUBROUTINE FOR JACOBIAN METRIX
C*  IF IA=1, ACAP MATRIX
C*  IF IA=2, BCAP MATRIX
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >             P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >          (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION A(4,4),B(4,4),C(4,4),TEMP(4,4),BB(4,4),DIAG(4)
C*****************************************************************
      ENTRY JACOB(IA,A,I,J)
      IF(IA.EQ.2)GO TO 10
      CX=SAIX(I,J)
      CY=SAIY(I,J)
      CONTRA=UN(I,J)
      GO TO 20
   10 CX=ETAX(I,J)
      CY=ETAY(I,J)
      CONTRA=VN(I,J)
   20 CONTINUE
      PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
      A(1,1)=0.0D0
      A(1,2)=CX
      A(1,3)=CY
      A(1,4)=0.D0
      A(2,1)=CX*PHI2-U(I,J)*CONTRA
      A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
      A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
      A(2,4)=GM1(I,J)*CX
      A(3,1)=CY*PHI2-V(I,J)*CONTRA
      A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
      A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
      A(3,4)=GM1(I,J)*CY
      A(4,1)=CONTRA*(2.*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
      A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
```

```
     > *U(I,J)
      A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
     > *V(I,J)
      A(4,4)=GAMMA(I,J)*CONTRA
      RETURN
C*
C*   SPLITTED JACOBIAN MATRIX IN XI-DIRECTION
C*
      ENTRY AJACOB(IA,A,I,J)
C*
C*     FOR THE FIRST ITERATION TURN OFF A MINUS
C*
      IF(NADV.EQ.1.AND.IA.EQ.2) THEN
       CALL SZERO(4,A)
       RETURN
      ENDIF
C     WRITE(6,*) I,J,RHO(I,J)
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCO=CX*CO
      EIG1=UN(I,J)
      EIG2=UN(I,J)
      EIG3=UN(I,J)+CXCO
      EIG4=UN(I,J)-CXCO
      IF(IA.EQ.1)THEN
       DIAG(1)=0.5*(EIG1+DABS(EIG1))
       DIAG(2)=DIAG(1)
       DIAG(3)=0.5*(EIG3+DABS(EIG3))
       DIAG(4)=0.5*(EIG4+DABS(EIG4))
      ELSE
       DIAG(1)=0.5*(EIG1-DABS(EIG1))
       DIAG(2)=DIAG(1)
       DIAG(3)=0.5*(EIG3-DABS(EIG3))
       DIAG(4)=0.5*(EIG4-DABS(EIG4))
      ENDIF
      CALL EIGEN(1,BB,I,J)
      DO 40 II=1,4
      DO 40 JJ=1,4
      TEMP(II,JJ)=DIAG(II)*BB(II,JJ)
 40   CONTINUE
      CALL EIGAR(BB,I,J)
      CALL MMM(4,BB,TEMP,A)
      RETURN
C*
C*    TRUE JACOBIAN FOR DE+-/DQ
C*
      ENTRY TRUEJ(IA,A,I,J)
C   CHECK THE FOURTH EIGEN VALUE
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCO=CX*CO
      EIG4=UN(I,J)-CXCO
      IF(UN(I,J).LT.0.D0)GOTO 60
      IF(EIG4.LT.0.D0)GOTO 50
C
```

```
      IF(IA.EQ.1)THEN
      CX=SAIX(I,J)
      CY=SAIY(I,J)
      CONTRA=UN(I,J)
      PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
      A(1,1)=0.0D0
      A(1,2)=CX
      A(1,3)=CY
      A(1,4)=0.D0
      A(2,1)=CX*PHI2-U(I,J)*CONTRA
      A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
      A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
      A(2,4)=GM1(I,J)*CX
      A(3,1)=CY*PHI2-V(I,J)*CONTRA
      A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
      A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
      A(3,4)=GM1(I,J)*CY
      A(4,1)=CONTRA*(2.*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
      A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
     > *U(I,J)
      A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
     > *V(I,J)
      A(4,4)=GAMMA(I,J)*CONTRA
      ELSE
      CALL SZERO(4,A)
      ENDIF
      RETURN
C
 50   CONTINUE
      IF(NADV.EQ.1.AND.IA.EQ.2)THEN
       CALL SZERO(4,A)
       RETURN
      ELSE
      PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
      ERC=E(I,J)/RHO(I,J)/C0
      ECR=E(I,J)*C0/RHO(I,J)
      R1=SAIX(I,J)
      R2=SAIY(I,J)
      R1T=R1/CX
      R2T=R2/CX
      G2M2=(2.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
      G23G=(-GAMMA(I,J)**2+3.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
      G34G=(3.*GAMMA(I,J)-2.)*.25/GAMMA(I,J)
      GM12=GM1(I,J)**2*.5/GAMMA(I,J)
      CGEC=C0*.5/GAMMA(I,J)-0.25*GM1(I,J)*ERC
      RKUU=CX*U(I,J)+R1T*UN(I,J)
      RKVU=CX*V(I,J)+R2T*UN(I,J)
      U2V2=PHI2/GM1(I,J)*2.
      RKU2=.25*GM1(I,J)*(CX*.5*U2V2+UN(I,J)**2/CX)
C
       IF(IA.EQ.1)THEN
      A(1,1)=.25*GM1(I,J)*CX*ERC
      A(1,2)=G2M2*R1-.25*GM1(I,J)*CX*U(I,J)/C0
      A(1,3)=G2M2*R2-.25*GM1(I,J)*CX*V(I,J)/C0
      A(1,4)=.25*GM1(I,J)*CX/C0
```

```
      A(2,1)=-G2M2*U(I,J)*UN(I,J)+.5*R1*PHI2-CGEC*RKUU
      A(2,2)=G23G*R1*U(I,J)+G2M2*UN(I,J)+.5*(CX+R1*R1T)/GAMMA(I,J)*C0-
     >       0.25*GM1(I,J)*U(I,J)/C0*RKUU
      A(2,3)=G2M2*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)+.5*R1T*R2
     >  /GAMMA(I,J)*C0-0.25*GM1(I,J)*V(I,J)/C0*RKUU
      A(2,4)=.5*GM1(I,J)*R1+.25*GM1(I,J)*RKUU/C0
      A(3,1)=-G2M2*V(I,J)*UN(I,J)+0.5*R2*PHI2-CGEC*RKVU
      A(3,2)=G2M2*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)+0.5*R1*R2T
     > /GAMMA(I,J)*C0-0.25*GM1(I,J)*U(I,J)/C0*RKVU
      A(3,3)=G2M2*UN(I,J)+G23G*R2*V(I,J)+(CX+R2T*R2)*.5/GAMMA(I,J)*C0-
     >       0.25*GM1(I,J)*V(I,J)/C0*RKVU
      A(3,4)=.5*GM1(I,J)*R2+.25*GM1(I,J)*RKVU/C0
      A(4,1)=GM12*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)
     > /RHO(I,J)+CX/GAMMA(I,J)*PHI2*C0-UN(I,J)**2*C0/GAMMA(I,J)/CX
     > -.25*CX*ECR+RKU2*ERC
      A(4,2)=-GM12*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -GM1(I,J)*.5/GAMMA(I,J)*R1*PHI2-G34G*CX*U(I,J)*C0+R1T
     >   /GAMMA(I,J)*UN(I,J)*C0-RKU2*U(I,J)/C0
      A(4,3)=-GM12*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -GM1(I,J)*.5/GAMMA(I,J)*R2*PHI2-G34G*CX*V(I,J)*C0+R2T
     > /GAMMA(I,J)*UN(I,J)*C0-RKU2*V(I,J)/C0
      A(4,4)=.5*GAMMA(I,J)*UN(I,J)+.75*CX*C0+RKU2/C0
      ELSE
      G11G=(1.+GAMMA(I,J)-GAMMA(I,J)**2)*.5/GAMMA(I,J)
      G22M=(GAMMA(I,J)**2-1.)*.5/GAMMA(I,J)
      A(1,1)=-.25*GM1(I,J)*CX*ERC
      A(1,2)=.5/GAMMA(I,J)*R1+.25*GM1(I,J)*CX*U(I,J)/C0
      A(1,3)=.5/GAMMA(I,J)*R2+.25*GM1(I,J)*CX*V(I,J)/C0
      A(1,4)=-.25*GM1(I,J)*CX/C0
      A(2,1)=-.5/GAMMA(I,J)*U(I,J)*UN(I,J)+.5*R1*PHI2+CGEC*RKUU
      A(2,2)=G11G*R1*U(I,J)+.5/GAMMA(I,J)*UN(I,J)-.5*(CX+R1*R1T)
     > /GAMMA(I,J)*C0+0.25*GM1(I,J)*U(I,J)/C0*RKUU
      A(2,3)=.5/GAMMA(I,J)*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)-.5*R1T*R2
     >  /GAMMA(I,J)*C0+0.25*GM1(I,J)*V(I,J)/C0*RKUU
      A(2,4)=.5*GM1(I,J)*R1-.25*GM1(I,J)*RKUU/C0
      A(3,1)=-.5/GAMMA(I,J)*V(I,J)*UN(I,J)+0.5*R2*PHI2+CGEC*RKVU
      A(3,2)=.5/GAMMA(I,J)*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)-0.5*R1*R2T
     >  /GAMMA(I,J)*C0+0.25*GM1(I,J)*U(I,J)/C0*RKVU
      A(3,3)=.5/GAMMA(I,J)*UN(I,J)+G11G*R2*V(I,J)-(CX+R2T*R2)*.5
     >  /GAMMA(I,J)*C0+0.25*GM1(I,J)*V(I,J)/C0*RKVU
      A(3,4)=.5*GM1(I,J)*R2-.25*GM1(I,J)*RKVU/C0
      A(4,1)=G22M*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)/RHO(I,J)-
     >       CX/GAMMA(I,J)*PHI2*C0+UN(I,J)**2*C0/GAMMA(I,J)/CX
     > +.25*CX*ECR-RKU2*ERC
      A(4,2)=-G22M*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R1*PHI2+G34G*CX*U(I,J)
     > *C0-R1T/GAMMA(I,J)*UN(I,J)*C0+RKU2*U(I,J)/C0
      A(4,3)=-G22M*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R2*PHI2+G34G*CX*V(I,J)
     > *C0-R2T/GAMMA(I,J)*UN(I,J)*C0+RKU2*V(I,J)/C0
      A(4,4)=.5*GAMMA(I,J)*UN(I,J)-.75*CX*C0-RKU2/C0
      ENDIF
      ENDIF
      RETURN
60    CONTINUE
```

```
C*
C* REVERSE FLOW REGION
C*
      IF(NADV.EQ.1) THEN
       WRITE(6,1010)
1010   FORMAT(' *** REVERSE FLOW FOR PNS MARCHING ***')
       RETURN
      ENDIF
      EIG3=UN(I,J)+CXCO
      IF(EIG3.LT.0.DO)THEN
       IF(IA.EQ.1)THEN
        CALL SZERO(4,A)
        RETURN
       ELSE
        CX=SAIX(I,J)
        CY=SAIY(I,J)
        CONTRA=UN(I,J)
        PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
        A(1,1)=0.0DO
        A(1,2)=CX
        A(1,3)=CY
        A(1,4)=0.DO
        A(2,1)=CX*PHI2-U(I,J)*CONTRA
        A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
        A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
        A(2,4)=GM1(I,J)*CX
        A(3,1)=CY*PHI2-V(I,J)*CONTRA
        A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
        A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
        A(3,4)=GM1(I,J)*CY
        A(4,1)=CONTRA*(2.*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
        A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
     > *U(I,J)
        A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
     > *V(I,J)
        A(4,4)=GAMMA(I,J)*CONTRA
        RETURN
       ENDIF
      ENDIF
C
      PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
      ERC=E(I,J)/RHO(I,J)/CO
      ECR=E(I,J)*CO/RHO(I,J)
      R1=SAIX(I,J)
      R2=SAIY(I,J)
      R1T=R1/CX
      R2T=R2/CX
      G2M2=(2.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
      G23G=(-GAMMA(I,J)**2+3.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
      G34G=(3.*GAMMA(I,J)-2.)*.25/GAMMA(I,J)
      GM12=GM1(I,J)**2*.5/GAMMA(I,J)
      CGEC=CO*.5/GAMMA(I,J)-0.25*GM1(I,J)*ERC
      RKUU=CX*U(I,J)+R1T*UN(I,J)
      RKVU=CX*V(I,J)+R2T*UN(I,J)
      U2V2=PHI2/GM1(I,J)*2.
```

```
      RKU2=.25*GM1(I,J)*(CX*.5*U2V2+UN(I,J)**2/CX)
      G11G=(1.+GAMMA(I,J)-GAMMA(I,J)**2)*.5/GAMMA(I,J)
      G22M=(GAMMA(I,J)**2-1.)*.5/GAMMA(I,J)
C
      IF(IA.EQ.1)THEN
      A(1,1)=.25*GM1(I,J)*CX*ERC
      A(1,2)=0.5/GAMMA(I,J)*R1-.25*GM1(I,J)*CX*U(I,J)/CO
      A(1,3)=0.5/GAMMA(I,J)*R2-.25*GM1(I,J)*CX*V(I,J)/CO
      A(1,4)=.25*GM1(I,J)*CX/CO
      A(2,1)=-0.5/GAMMA(I,J)*U(I,J)*UN(I,J)+.5*R1*PHI2-CGEC*RKUU
      A(2,2)=G11G*R1*U(I,J)+0.5/GAMMA(I,J)*UN(I,J)+.5*(CX+R1*R1T)
     > /GAMMA(I,J)*CO-0.25*GM1(I,J)*U(I,J)/CO*RKUU
      A(2,3)=0.5/GAMMA(I,J)*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)+.5*R1T*R2
     > /GAMMA(I,J)*CO-0.25*GM1(I,J)*V(I,J)/CO*RKUU
      A(2,4)=.5*GM1(I,J)*R1+.25*GM1(I,J)*RKUU/CO
      A(3,1)=-0.5/GAMMA(I,J)*V(I,J)*UN(I,J)+0.5*R2*PHI2-CGEC*RKVU
      A(3,2)=0.5/GAMMA(I,J)*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)+0.5*R1
     > *R2T/GAMMA(I,J)*CO-0.25*GM1(I,J)*U(I,J)/CO*RKVU
      A(3,3)=0.5/GAMMA(I,J)*UN(I,J)+G11G*R2*V(I,J)+(CX+R2T*R2)*.5
     > /GAMMA(I,J)*CO-0.25*GM1(I,J)*V(I,J)/CO*RKVU
      A(3,4)=.5*GM1(I,J)*R2+.25*GM1(I,J)*RKVU/CO
      A(4,1)=G22M*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)/RHO(I,J)+
     >       CX/GAMMA(I,J)*PHI2*CO-UN(I,J)**2*CO/GAMMA(I,J)/CX-.25
     > *CX*ECR+RKU2*ERC
      A(4,2)=-G22M*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R1*PHI2-G34G*CX*U(I,J)
     >  *CO+R1T/GAMMA(I,J)*UN(I,J)*CO-RKU2*U(I,J)/CO
      A(4,3)=-G22M*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R2*PHI2-G34G*CX*V(I,J)
     > *CO+R2T/GAMMA(I,J)*UN(I,J)*CO-RKU2*V(I,J)/CO
      A(4,4)=.5*GAMMA(I,J)*UN(I,J)+.75*CX*CO+RKU2/CO
      ELSE
      A(1,1)=-.25*GM1(I,J)*CX*ERC
      A(1,2)=G2M2*R1+.25*GM1(I,J)*CX*U(I,J)/CO
      A(1,3)=G2M2*R2+.25*GM1(I,J)*CX*V(I,J)/CO
      A(1,4)=-.25*GM1(I,J)*CX/CO
      A(2,1)=-G2M2*U(I,J)*UN(I,J)+.5*R1*PHI2+CGEC*RKUU
      A(2,2)=G23G*R1*U(I,J)+G2M2*UN(I,J)-.5*(CX+R1*R1T)/GAMMA(I,J)
     >  *CO+0.25*GM1(I,J)*U(I,J)/CO*RKUU
      A(2,3)=G2M2*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)-.5*R1T*R2
     > /GAMMA(I,J)*CO+0.25*GM1(I,J)*V(I,J)/CO*RKUU
      A(2,4)=.5*GM1(I,J)*R1-.25*GM1(I,J)*RKUU/CO
      A(3,1)=-G2M2*V(I,J)*UN(I,J)+0.5*R2*PHI2+CGEC*RKVU
      A(3,2)=G2M2*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)-0.5*R1*R2T
     >  /GAMMA(I,J)*CO+0.25*GM1(I,J)*U(I,J)/CO*RKVU
      A(3,3)=G2M2*UN(I,J)+G23G*R2*V(I,J)-(CX+R2T*R2)*.5/GAMMA(I,J)*CO+
     >       0.25*GM1(I,J)*V(I,J)/CO*RKVU
      A(3,4)=.5*GM1(I,J)*R2-.25*GM1(I,J)*RKVU/CO
      A(4,1)=GM12*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)
     >  /RHO(I,J)-CX/GAMMA(I,J)*PHI2*CO+UN(I,J)**2*CO/GAMMA(I,J)/CX+.25
     > *CX*ECR-RKU2*ERC
      A(4,2)=-GM12*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
     >       -GM1(I,J)*.5/GAMMA(I,J)*R1*PHI2+G34G*CX*U(I,J)*CO-R1T
     >  /GAMMA(I,J)*UN(I,J)*CO+RKU2*U(I,J)/CO
      A(4,3)=-GM12*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
```

```
     >       -GM1(I,J)*.5/GAMMA(I,J)*R2*PHI2+G34G*CX*V(I,J)*CO-R2T
     > /GAMMA(I,J)*UN(I,J)*CO+RKU2*V(I,J)/CO
      A(4,4)=.5*GAMMA(I,J)*UN(I,J)-.75*CX*CO-RKU2/CO
      ENDIF
      RETURN
C*
C* VISCOUS TERM JACOBIAN MATRIX
C*
      ENTRY VJACOB(A,B,C,I,J)
      JP1=J+1
      JM1=J-1
      ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
      ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
      YYP =0.5*(Y(I,J)+Y(I,JP1))
      YYM =0.5*(Y(I,J)+Y(I,JM1))
      YJP =RJ(I,JP1)/Y(I,JP1)
      IF(JM1.EQ.1)THEN
      YJM=0.
      ELSE
      YJM =RJ(I,JM1)/Y(I,JM1)
      ENDIF
      IF(PRNT.EQ.0.DO)THEN
      GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
      GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
      GKCPP=ZMUP*GAMP/PRN
      GKCPM=ZMUM*GAMM/PRN
      ELSE
      ZMUTP = 0.5*(ZMUT(JP1)+ZMUT(J))
      ZMUTM = 0.5*(ZMUT(JM1)+ZMUT(J))
      ZMULP = ZMUP - ZMUTP
      ZMULM = ZMUM - ZMUTM
      GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
      GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
      GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
      GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
      ENDIF
      EXJ=ETAX(I,J)/RJ(I,J)
      EYJ=ETAY(I,J)/RJ(I,J)
      ZMUU=ZMU(I,J)
      OR=1./RHO(I,J)
      ORP=1./RHO(I,JP1)
      ORM=1./RHO(I,JM1)
      ZMURP=ZMU(I,JP1)*ORP
      ZMURM=ZMU(I,JM1)*ORM
      UR =U(I,J)*OR
      URP=U(I,JP1)*ORP
      URM=U(I,JM1)*ORM
      VR =V(I,J)*OR
      VRM=V(I,JM1)*ORM
      VRP=V(I,JP1)*ORP
      UMRP=URP*ZMU(I,JP1)
      UMRM=URM*ZMU(I,JM1)
      VMRP=VRP*ZMU(I,JP1)
      VMRM=VRM*ZMU(I,JM1)
      U2R =UR*U(I,J)
```

```
      U2RP=URP*U(I,JP1)
      U2RM=URM*U(I,JM1)
      V2R =VR*V(I,J)
      V2RP=VRP*V(I,JP1)
      V2RM=VRM*V(I,JM1)
      UVR =UR*V(I,J)
      UVRP=URP*V(I,JP1)
      UVRM=URM*V(I,JM1)
      ER2 =E(I,J)*OR**2
      ER2P=E(I,JP1)*ORP**2
      ER2M=E(I,JM1)*ORM**2
      ZRYJP=ZMURP*YJP
      ZRYJM=ZMURM*YJM
      ORYJP=ORP*YJP
      ORYJM=ORM*YJM
      VMRP=-ZMURP*V(I,JP1)*YJP
      VMRM=-ZMURM*V(I,JM1)*YJM
      URYJP=-URP*YJP
      URYJM=-URM*YJM
      VYJP=2.*ZMU(I,JP1)*VRP*YJP
      VYJM=2.*ZMU(I,JM1)*VRM*YJM
      V2YJP=-V2RP*2.*ZMU(I,JP1)*YJP
      V2YJM=-V2RM*2.*ZMU(I,JM1)*YJM
      UVYJP=-2.*ZMU(I,JP1)*UVRP*YJP
      UVYJM=-2.*ZMU(I,JM1)*UVRM*YJM
      VYJP2=VYJP*0.5
      VYJM2=0.5*VYJM
      UYJP=ZMU(I,JP1)*URP*YJP
      UYJM=ZMU(I,JM1)*URM*YJM
      AAP1= ZMUP*A1(I,J)*YYP
      AAP2= ZMUP*A2(I,J)*YYP
      AAP3= ZMUP*A3(I,J)*YYP
      AAP4= GKCPP*A4(I,J)*YYP
      AAM1= ZMUM*A1(I,JM1)*YYM
      AAM2= ZMUM*A2(I,JM1)*YYM
      AAM3 =ZMUM*A3(I,JM1)*YYM
      AAM4 =GKCPM*A4(I,JM1)*YYM
      IF(JM1.EQ.1)THEN
      CALL SZERO(4,A)
      ELSE
      A(1,1) =0.
      A(1,2) =0.
      A(1,3) =0.
      A(1,4) =0.
      A21=(AAM1*URM+AAM2*VRM)*RJ(I,JM1)/Y(I,JM1)
      A(2,1) =A21-1./3.*EXJ*VMRM
      A(2,2) =-AAM1*ORM*RJ(I,JM1)/Y(I,JM1)
      A(2,3) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)-1./3.*EXJ*ZRYJM
      A(2,4) =0.
      A31=(AAM2*URM+AAM3*VRM)*RJ(I,JM1)/Y(I,JM1)
      A(3,1) =A31+1./3.*ZMU(I,J)
     *          *EXJ*URYJM
      A(3,2) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)+1./3.*ZMU(I,J)*EXJ*ORYJM
      A(3,3) =-AAM3*ORM*RJ(I,JM1)/Y(I,JM1)
      A(3,4) =0.
```

```
      A(4,1) =(-AAM4*(-ER2M+U2RM+V2RM)+AAM1*U2RM+AAM3*V2RM+
     +          2.*AAM2*UVRM)*RJ(I,JM1)/Y(I,JM1)-
     +          1./3.*EYJ*V2YJM-1./3.*EXJ*UVYJM
      A(4,2) =AAM4*URM*RJ(I,JM1)/Y(I,JM1)-A21-1./3.*EXJ*VYJM2
      A(4,3) =AAM4*VRM*RJ(I,JM1)/Y(I,JM1)-A31-1./3.*EYJ*VYJM-
     *          1./3.*EXJ*UYJM
      A(4,4) =-AAM4*ORM*RJ(I,JM1)/Y(I,JM1)
      ENDIF
      C(1,1) =0.
      C(1,2) =0.
      C(1,3) =0.
      C(1,4) =0.
      C21=(AAP1*URP+AAP2*VRP)*RJ(I,JP1)/Y(I,JP1)
      C(2,1) =C21+1./3.*EXJ*VMRP
      C(2,2) =-AAP1*ORP*RJ(I,JP1)/Y(I,JP1)
      C(2,3) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)+1./3.*EXJ*ZRYJP
      C(2,4) =0.
      C31=(AAP2*URP+AAP3*VRP)*RJ(I,JP1)/Y(I,JP1)
      C(3,1) =C31-1./3.*ZMU(I,J)
     *         *EXJ*URYJP
      C(3,2) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)-1./3.*ZMU(I,J)*EXJ*ORYJP
      C(3,3) =-AAP3*ORP*RJ(I,JP1)/Y(I,JP1)
      C(3,4) =0.
      C(4,1) =(-AAP4*(-ER2P+U2RP+V2RP)+AAP1*U2RP+AAP3*V2RP+
     +          2.*AAP2*UVRP)*RJ(I,JP1)/Y(I,JP1)+
     +          1./3.*EYJ*V2YJP+1./3.*EXJ*UVYJP
      C(4,2) =AAP4*URP*RJ(I,JP1)/Y(I,JP1)-C21+1./3.*EXJ*VYJP2
      C(4,3) =AAP4*VRP*RJ(I,JP1)/Y(I,JP1)-C31+1./3.*EYJ*VYJP+
     +          1./3.*EXJ*UYJP
      C(4,4) =-AAP4*ORP*RJ(I,JP1)/Y(I,JP1)
      AA1 =AAP1+AAM1
      AA2 =AAP2+AAM2
      AA3 =AAP3+AAM3
      AA4 =AAP4+AAM4
      B(1,1) =0.
      B(1,2) =0.
      B(1,3) =0.
      B(1,4) =0.
      B(2,1) =(-AA1*UR-AA2*VR)*RJ(I,J)/Y(I,J)
      B(2,2) =AA1*OR*RJ(I,J)/Y(I,J)
      B(2,3) =AA2*OR*RJ(I,J)/Y(I,J)
      B(2,4) =0.
      B(3,1) =(-AA2*UR-AA3*VR)*RJ(I,J)/Y(I,J)
      B(3,2) =AA2*OR*RJ(I,J)/Y(I,J)
      B(3,3) =AA3*OR*RJ(I,J)/Y(I,J)
      B(3,4) =0.
      B(4,1) =(AA4*(-ER2+U2R+V2R)-AA1*U2R-AA3*V2R-
     *          2.*AA2*UVR)*RJ(I,J)/Y(I,J)
      B(4,2) =-AA4*UR*RJ(I,J)/Y(I,J)-B(2,1)
      B(4,3) =-AA4*VR*RJ(I,J)/Y(I,J)-B(3,1)
      B(4,4) =AA4*OR*RJ(I,J)/Y(I,J)
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE EIGMTX
```

```
C*
C*  SUBROUTINE FOR EIGENVECTOR MATRIX CALCULATION
C*  IF IA=1  L FOR ACAP
C*  IF IA=2  L FOR BCAP
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >             P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     *CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >             ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION A(4,4)
C*****************************************************************
      ENTRY EIGEN(IA,A,I,J)
      IF(IA.EQ.2)GO TO 10
      CX=SAIX(I,J)
      CY=SAIY(I,J)
      GO TO 20
   10 CX=ETAX(I,J)
      CY=ETAY(I,J)
   20 CONTINUE
      SQ2=DSQRT(2.D0)
      C=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      C1=CX/DSQRT(CX**2+CY**2)
      C2=CY/DSQRT(CX**2+CY**2)
      A(1,1)=1.-0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/C**2
      A(1,2)=GM1(I,J)*U(I,J)/C**2
      A(1,3)=GM1(I,J)*V(I,J)/C**2
      A(1,4)=-GM1(I,J)/C**2
      A(2,1)=(-C2*U(I,J)+C1*V(I,J))/RHO(I,J)
      A(2,2)=C2/RHO(I,J)
      A(2,3)=-C1/RHO(I,J)
      A(2,4)=0.
      A(3,1)=-(C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+
     >       0.5/SQ2*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/RHO(I,J)/C
      A(3,2)=C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/C
      A(3,3)=C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/C
      A(3,4)=GM1(I,J)/SQ2/RHO(I,J)/C
      A(4,1)=(C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+0.5/SQ2*GM1(I,J)*
     >       (U(I,J)**2+V(I,J)**2)/RHO(I,J)/C
      A(4,2)=-C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/C
      A(4,3)=-C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/C
      A(4,4)=GM1(I,J)/SQ2/RHO(I,J)/C
```

```
      RETURN
C*
C* LEFT & RIGHT EIGENMATRIX FOR XI DIRECTION
C*
      ENTRY EIGAR(A,I,J)
      CX=SAIX(I,J)
      CY=SAIY(I,J)
      SQ2=1./DSQRT(2.D0)
      C=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CXCY=1./DSQRT(CX**2+CY**2)
      C1=CX*CXCY
      C2=CY*CXCY
      A(1,1)=1.
      A(1,2)=0.
      A(1,3)=RHO(I,J)*SQ2/C
      A(1,4)=A(1,3)
      A(2,1)=U(I,J)
      A(2,2)=RHO(I,J)*C2
      A(2,3)=SQ2*RHO(I,J)*(U(I,J)/C+C1)
      A(2,4)=SQ2*RHO(I,J)*(U(I,J)/C-C1)
      A(3,1)=V(I,J)
      A(3,2)=-RHO(I,J)*C1
      A(3,3)=SQ2*RHO(I,J)*(V(I,J)/C+C2)
      A(3,4)=SQ2*RHO(I,J)*(V(I,J)/C-C2)
      A(4,1)=0.5*(U(I,J)**2+V(I,J)**2)
      A(4,2)=RHO(I,J)*(U(I,J)*C2-V(I,J)*C1)
      TEMP=0.5*SQ2*RHO(I,J)*(U(I,J)**2+V(I,J)**2)/C
     +           +RHO(I,J)*SQ2*C/GM1(I,J)
      RUC=SQ2*RHO(I,J)*(U(I,J)*C1+V(I,J)*C2)
      A(4,3)=TEMP+RUC
      A(4,4)=TEMP-RUC
      RETURN
      END
C-----------------------------------------------------------------
C-----------------------------------------------------------------
      SUBROUTINE COEFY(I)
C*
C*  SETTING COEFFICIENTS FOR LY-OPERATOR
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >     ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >              ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
```

```
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*************************************************************
      DIMENSION AM(4,4,JZ),BM(4,4,JZ),CM(4,4,JZ),DM(4,JZ)
      DIMENSION DTEMP(4),ISUB(JZ)
      DIMENSION B(4,4),BL1(4,4),D(4,4),A(4,4),AJM(4,4)
CHOIBEGIN
      DIMENSION AMIL1(4,4),BMIL1(4,4),CMIL1(4,4),DMIL1(4)
      DIMENSION BJ2(4,4),BJ1(4,4),DD(4,4)
      DIMENSION AMIL(4,4),BMIL(4,4),CMIL(4,4),DMIL(4)
      DIMENSION AMINV(4,4)
      DIMENSION AB1(4,4),AB2(4,4),AB3(4,4),AB4(4,4)
      DIMENSION D1(4),D2(4),D3(4),D4(4)
CHOIEND
      DATA ISUB/JZ*0/
C*************************************************************
C*  CHECK THE SONIC POINT AT DOWNSTREAM END
      IF(IVISC.NE.1)GOTO 15
      IF(I.NE.IL)GOTO 15
      DO 5 J=1,JL
      C0=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CONTRA=UN(I,J)-DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)*C0
      IF(CONTRA.LT.0.D0)THEN
       ISUB(J)=1
      ELSE
       ISUB(J)=0
      ENDIF
      IF(UN(I,J).LT.0.D0)ISUB(J)=2
      IF(FB.EQ.0.D0)ISUB(J)=0
      IF(NADV.EQ.1)ISUB(J)=0
  5   CONTINUE
 15   CONTINUE
C*
C* ON THE CENTER LINE OF THE NOZZLE AT J=1
C*
      J=1
      CALL SZERO(4,AM(1,1,J))
      CALL SZERO(4,BM(1,1,J))
      DO 20 M=1,4
      DM(M,J)=0.
      BM(M,M,J)=BM(M,M,J)+1.0
 20   CONTINUE
      CALL SZERO(4,CM(1,1,J))
C*
C*  INTERIOR NODS
C*
      DO 80 J=2,JL1
      TAUD=0.5D0*DELTAU(I,J)*THETA/EY1
      TAUD2=2.*TAUD
      JM1=J-1
      JP1=J+1
      CALL JACOB(2,B,I,JM1)
      CALL SMM(4,-TAUD,B,AM(1,1,J))
      CALL SZERO(4,BM(1,1,J))
      DO 60 M=1,4
  60  BM(M,M,J)=BM(M,M,J)+1.
```

```
      IF(I.EQ.IL.AND.ISUB(J).NE.0)THEN
       CALL AJACOB(1,A,I,J)
       CALL SZERO(4,AJM)
      ELSE
       CALL TRUEJ(1,A,I,J)
       CALL TRUEJ(2,AJM,I,J)
      ENDIF
      CALL DHDQ(D,I,J)
      DO 65 M=1,4
      DO 65 N=1,4
      BM(M,N,J)=BM(M,N,J)-TAUD2*(D(M,N)-A(M,N)+AJM(M,N))
      IF(I.NE.2.AND.I.LT.IL1)BM(M,N,J)=BM(M,N,J)+NORD*TAUD*
     *      (A(M,N)-AJM(M,N))
   65 CONTINUE
      CALL JACOB(2,B,I,JP1)
      CALL SMM(4,TAUD,B,CM(1,1,J))
C*
C*   INSERT VISCOUS JACOBIAN LHS HERE
C*
      IF(IVISC.EQ.1)THEN
       CALL VJACOB(A,B,D,I,J)
        DO 68 M=1,4
        DO 68 N=1,4
         AM(M,N,J)=AM(M,N,J)+DELTAU(I,J)*A(M,N)
         BM(M,N,J)=BM(M,N,J)+DELTAU(I,J)*B(M,N)
   68    CM(M,N,J)=CM(M,N,J)+DELTAU(I,J)*D(M,N)
      ELSE
      END IF
      DO 70 K=1,4
   70 DM(K,J)=DQ(I,J,K)
C
C    SUBSONIC REGION KEEP BACK PRESSURE
C
      IF(IVISC.EQ.1.AND.(I.EQ.IL.AND.ISUB(J).EQ.1))THEN
      CALL EIGEN(1,BL1,I,J)
      DO 72 K=1,4
   72 BL1(4,K)=0.
      CALL MMM(4,BL1,AM(1,1,J),A)
      CALL MMM(4,BL1,BM(1,1,J),B)
      CALL MMM(4,BL1,CM(1,1,J),D)
      DO 74 M=1,4
      DO 74 N=1,4
      AM(M,N,J)=A(M,N)
      BM(M,N,J)=B(M,N)
   74 CM(M,N,J)=D(M,N)
      DO 76 M=1,4
      DTEMP(M)=0.
      DO 76 K=1,4
      DTEMP(M)=DTEMP(M)+BL1(M,K)*DM(K,J)
   76 CONTINUE
      DO 78 M=1,4
   78 DM(M,J)=DTEMP(M)
      BM(4,1,J)=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/Y(I,J)
      BM(4,2,J)=-GM1(I,J)*U(I,J)/Y(I,J)
      BM(4,3,J)=-GM1(I,J)*V(I,J)/Y(I,J)
```

```
      BM(4,4,J)=GM1(I,J)/Y(I,J)
      IF(PB.NE.0.D0)THEN
      DM(4,J)=(PB-P(I,J))/RJ(I,J)
      ELSE
      DM(4,J)=0.
      ENDIF
      ELSE
      END IF
C
C  REVERSE FLOW REGION
C
      IF(IVISC.EQ.1.AND.(I.EQ.IL.AND.ISUB(J).EQ.2))THEN
      CALL EIGEN(1,BL1,I,J)
      DO 73 K=1,4
      BL1(1,K)=0.
      BL1(2,K)=0.
   73 BL1(4,K)=0.
      CALL MMM(4,BL1,AM(1,1,J),A)
      CALL MMM(4,BL1,BM(1,1,J),B)
      CALL MMM(4,BL1,CM(1,1,J),D)
      DO 75 M=1,4
      DO 75 N=1,4
      AM(M,N,J)=A(M,N)
      BM(M,N,J)=B(M,N)
   75 CM(M,N,J)=D(M,N)
      DO 77 M=1,4
      DTEMP(M)=0.
      DO 77 K=1,4
      DTEMP(M)=DTEMP(M)+BL1(M,K)*DM(K,J)
   77 CONTINUE
      DO 79 M=1,4
   79 DM(M,J)=DTEMP(M)
      RJYY=RJ(I,J)/Y(I,J)
      RCV=RHO(I,J)*CV(I,J)
      RJRCV=RJYY/RCV
      BM(1,1,J)=(-E(I,J)/RHO(I,J)+GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
     > +V(I,J)**2))*RJRCV
      BM(1,2,J)=-GM1(I,J)/GAMMA(I,J)*U(I,J)*RJRCV
      BM(1,3,J)=-GM1(I,J)/GAMMA(I,J)*V(I,J)*RJRCV
      BM(1,4,J)=RJRCV
      C1=(RHO(I,J)*E(I,J)-0.5*RHO(I,J)**2*(U(I,J)**2+V(I,J)**2))
      C2=(RHO(I,J)*E(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*RHO(I,J)**2*(U(I,J)**2
     >    +V(I,J)**2))
      C3=(C2/C1)**(GAMMA(I,J)/GM1(I,J))
      C4=GAMMA(I,J)/GM1(I,J)/C1*(C2/C1)**(1.D0/GM1(I,J))
      BM(2,1,J)=(0.5*(U(I,J)**2+V(I,J)**2)*C3+C4*E(I,J)*(C1-C2)/RHO(I,J)
     >   )*GM1(I,J)*RJYY
      BM(2,2,J)=(-U(I,J)*C3+C4*U(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
     > *GM1(I,J)*RJYY
      BM(2,3,J)=(-V(I,J)*C3+C4*V(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
     > *GM1(I,J)*RJYY
      BM(2,4,J)=(C3+C4*(C1-C2))*GM1(I,J)*RJYY
      BM(4,1,J)=-VN(I,J)*RJYY/RHO(I,J)
      BM(4,2,J)=ETAX(I,J)*RJYY/RHO(I,J)
      BM(4,3,J)=ETAY(I,J)*RJYY/RHO(I,J)
```

```
      BM(4,4,J)=0.
      TON=(E(I,J)/RHO(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
     > +V(I,J)**2))/CV(I,J)
      TT =(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
      PON=P(I,J)*(TON/TT)**(GAMMA(I,J)/GM1(I,J))
      DM(1,J)= (TWALL-TON)
      DM(2,J)= (PB-PON)
      DM(4,J)= -VN(I,J)
      END IF
C
CHOI
CHOI
      IF(IVISC.EQ.0.AND.J.EQ.JL1) GOTO 8001
      GO TO 80
 8001 DO 8002 M=1,4
      DO 8002 N=1,4
      AMIL1(M,N)=AM(M,N,JL1)
 8002 CONTINUE
      DO 8003 M=1,4
      DO 8003 N=1,4
      BMIL1(M,N)=BM(M,N,JL1)
 8003 CONTINUE
      DO 8004 M=1,4
      DO 8004 N=1,4
      CMIL1(M,N)=CM(M,N,JL1)
 8004 CONTINUE
      DO 8005 M=1,4
      DMIL1(M)=DM(M,JL1)
 8005 CONTINUE
CHOI
CHOI
  80  CONTINUE
C*
C* WALL  BOUNDARY CONDITION
C*
CHOI       J=JL
CHOI       TAUD=THETA*DELTAU(I,J)/EYI
CHOI       IF(IVISC.EQ.1)GOTO 111
CHOI       CALL SZERO(4,AM(1,1,J))
CHOI       CALL JACOB(2,B,I,J-1)
CHOI       CALL AJACOB(1,A,I,J)
CHOI       CALL AJACOB(2,AJM,I,J)
CHOI       CALL EIGEN(2,BL1,I,J)
CHOI       DO 90 M=1,3
CHOI       DO 90 N=1,4
CHOI       DO 90 K=1,4
CHOI  90   AM(M,N,J)=AM(M,N,J)-TAUD*BL1(M,K)*B(K,N)
CHOI       CALL SZERO(4,BM(1,1,J))
CHOI       CALL JACOB(2,B,I,J)
CHOI       CALL DHDQ(D,I,J)
CHOI       DO 100 M=1,3
CHOI       DO 100 N=1,4
CHOI       BM(M,N,J)=BM(M,N,J)+BL1(M,N)
CHOI       DO 100 K=1,4
CHOI  BM(M,N,J)=BM(M,N,J)+TAUD*BL1(M,K)*(B(K,N)+A(K,N)-D(K,N)-AJM(K,N))
```

```
CHOI        IF(I.NE.2.AND.I.LT.IL1) BM(M,N,J)=BM(M,N,J)+NORD*0.5*TAUD*
CHOI      *    BL1(M,K)*(A(K,N)-AJM(K,N))
CHOI 100  CONTINUE
CHOI
CHOIBEG
      J=JL
      TAUD=THETA*DELTAU(I,J)/EYI
      IF(IVISC.EQ.1) GOTO 111
      CALL JACOB(2,BJ2,I,J-2)
      CALL JACOB(2,BJ1,I,J-1)
      CALL JACOB(2,B,I,J)
      CALL AJACOB(1,A,I,J)
      CALL AJACOB(2,AJM,I,J)
      CALL EIGEN(2,BL1,I,J)
      DO 899 N=1,4
  899 BL1(4,N)=0.D0
      CALL HJAC(DD,J)
      DO 90 M=1,4
      DO 90 N=1,4
      AMIL(M,N)=0.5D0*BJ2(M,N)*TAUD
   90 CONTINUE
      DO 91 M=1,4
      DO 91 N=1,4
      BMIL(M,N)=-2.D0*BJ1(M,N)*TAUD
   91 CONTINUE
      CALL JACOB(2,B,I,J)
      CALL DHDQ(D,I,J)
      DO 100 M=1,4
      DO 100 N=1,4
      CMIL(M,N)=DD(M,N)+TAUD*(1.5D0*B(M,N)+A(M,N)-D(M,N)-AJM(M,N))
      IF(I.NE.2.AND.I.LT.IL1) CMIL(M,N)=CMIL(M,N)+NORD*0.5D0*TAUD*
     > (A(M,N)-AJM(M,N))
  100 CONTINUE
      DO 1001 M=1,4
 1001 DMIL(M)=DQ(I,JL,M)
C     DO 2001 M=1,4
CC    WRITE(6,2002) I,(AMIL1(M,N),N=1,4)
C2001 CONTINUE
C2002 FORMAT(2X,I5,2X,4D14.5)
      CALL INVER(4,AMIL1,AMINV)
      CALL MMM(4,AMINV,BMIL1,AB1)
      CALL MMM(4,AMIL,AB1,AB2)
      DO 101 M=1,4
      DO 101 N=1,4
  101 AB3(M,N)=AB2(M,N)-BMIL(M,N)
      CALL MMM(4,BL1,AB3,AB4)
      DO 102 M=1,4
      DO 102 N=1,4
  102 AM(M,N,J)=AB4(M,N)
      CALL MMM(4,AMINV,CMIL1,AB1)
      CALL MMM(4,AMIL,AB1,AB2)
      DO 103 M=1,4
      DO 103 N=1,4
  103 AB3(M,N)=AB2(M,N)-CMIL(M,N)
      CALL MMM(4,BL1,AB3,AB4)
```

```
      DO 104 M=1,4
      DO 104 N=1,4
  104 BM(M,N,J)=AB4(M,N)
      CALL MMV(4,AMINV,DMIL1,D1)
      CALL MMV(4,AMIL,D1,D2)
      DO 105 M=1,4
  105 D3(M)=D2(M)-DMIL(M)
      CALL MMV(4,BL1,D3,D4)
      DO 106 M=1,4
  106 DM(M,J)=D4(M)
CHOI
CHOIEND
      BM(4,1,J)=-VN(I,J)
      BM(4,2,J)=ETAX(I,J)
      BM(4,3,J)=ETAY(I,J)
      BM(4,4,J)=0.
      CALL SZERO(4,CM(1,1,J))
CHOI      DO 110 M=1,3
CHOI      DM(M,J)=0.
CHOI      DO 110 K=1,4
CHOI      DM(M,J)=DM(M,J)+BL1(M,K)*DQ(I,J,K)
CHOI 110  CONTINUE
C     WRITE(6,*) I,J,BM(4,1,J)
      DM(4,J)=0.
      GOTO 119
 111  CONTINUE
      CALL SZERO(4,AM(1,1,J))
      CALL SZERO(4,CM(1,1,J))
      CALL SZERO(4,BM(1,1,J))
      DO 112 M=1,4
      DM(M,J)=0.
 112  BM(M,M,J)=1.0
      IF(IWBC.EQ.1)THEN
       OR=1./RHO(I,J)
       ORCV=OR/CV(I,J)
       U2V2=U(I,J)**2+V(I,J)**2
       U2V21=U(I,JL1)**2+V(I,JL1)**2
       YJJL=RJ(I,JL)/Y(I,JL)
       YJJL1=RJ(I,JL1)/Y(I,JL1)
       BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV
       BM(1,2,J)=-U(I,J)*YJJL*ORCV
       BM(1,3,J)=-V(I,J)*YJJL*ORCV
       BM(1,4,J)=YJJL*ORCV
       BM(2,1,J)=0.
       BM(2,2,J)=YJJL
       BM(2,3,J)=0.
       BM(2,4,J)=0.
       BM(3,1,J)=0.
       BM(3,3,J)=YJJL
       BM(3,4,J)=0.
       C1=SAIX(I,J)*ETAX(I,J)+SAIY(I,J)*ETAY(I,J)
       C2=ETAX(I,J)**2+ETAY(I,J)**2
       CB=C1+C2
       IF(I.GT.2) CB=CB+0.5*FLOAT(NORD)*C1
       CD=C1*P(I-1,J)
```

```
      IF(I.GT.2) CD=CD+NORD*C1*(P(I-1,J)-0.5*P(I-2,J))
      BM(4,1,J)=0.5*U2V2*YJJL*GM1(I,J)*CB
      BM(4,2,J)=-U(I,J)*YJJL*GM1(I,J)*CB
      BM(4,3,J)=-V(I,J)*YJJL*GM1(I,J)*CB
      BM(4,4,J)=YJJL*GM1(I,J)*CB
      AM(4,1,J)=-0.5*U2V21*YJJL1*GM1(I,J)*C2
      AM(4,2,J)=U(I,J-1)*YJJL1*GM1(I,J)*C2
      AM(4,3,J)=V(I,J-1)*YJJL1*GM1(I,J)*C2
      AM(4,4,J)=-YJJL1*GM1(I,J)*C2
      DO 113 M=1,3
  113 DM(M,J)=0.
      TJJ=P(I,J)/RHO(I,J)/RGAS
      DM(1,J)=TWALL-TJJ
      DM(4,J)=CD+C2*P(I,JL1)-CB*P(I,JL)
C
C ADIABATIC WALL
C
      IF(IWALL.EQ.0)THEN
      ORCV=1./RHO(I,J)/CV(I,J)
      ORCV1=1./RHO(I,J-1)/CV(I,J-1)
      RUU=RGAS
      TIM1=P(I-1,J)/RHO(I-1,J)/RUU
      CD=C1*TIM1
      IF(I.GT.2) THEN
       TIM2=P(I-2,J)/RHO(I-2,J)/RUU
       CD=CD+NORD*C1*(TIM1-0.5*TIM2)
      ENDIF
      BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV*CB
      BM(1,2,J)=-U(I,J)*YJJL*ORCV*CB
      BM(1,3,J)=-V(I,J)*YJJL*ORCV*CB
      BM(1,4,J)=YJJL*ORCV*CB
      AM(1,1,J)=-(-E(I,J-1)*OR+U2V21)*YJJL1*ORCV1*C2
      AM(1,2,J)=U(I,J-1)*YJJL1*ORCV1*C2
      AM(1,3,J)=V(I,J-1)*YJJL1*ORCV1*C2
      AM(1,4,J)=-YJJL1*ORCV1*C2
      TJM1=P(I,J-1)/RHO(I,J-1)/RUU
      TJJ=P(I,J)/RHO(I,J)/RUU
      DM(1,J)=CD+C2*TJM1-CB*TJJ
      ENDIF
C
C WALL COOLING (FROM UPSTREAM TO DOWNSTREAM
C
      IF(IWALL.EQ.2.AND.IFLOW.EQ.1)THEN
      C1=C1/RJ(I,J)
      C2=C2/RJ(I,J)
      C3=BIOT/Y(I,J)
      CB=C1+C2+C3
      IF(I.GT.2) CB=CB+0.5*FLOAT(NORD)*(C1+C3)
      ORCV=1./RHO(I,J)/CV(I,J)
      ORCV1=1./RHO(I,J-1)/CV(I,J-1)
      RUU=RGAS
      TIM1=P(I-1,J)/RHO(I-1,J)/RUU
      CD=(C1+C3)*TIM1
      IF(I.GT.2) THEN
       TIM2=P(I-2,J)/RHO(I-2,J)/RUU
```

```
          CD=CD+NORD*(C1+C3)*(TIM1-0.5*TIM2)
         ENDIF
         BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV*CB
         BM(1,2,J)=-U(I,J)*YJJL*ORCV*CB
         BM(1,3,J)=-V(I,J)*YJJL*ORCV*CB
         BM(1,4,J)=YJJL*ORCV*CB
         AM(1,1,J)=-(-E(I,J-1)*OR+U2V21)*YJJL1*ORCV1*C2
         AM(1,2,J)=U(I,J-1)*YJJL1*ORCV1*C2
         AM(1,3,J)=V(I,J-1)*YJJL1*ORCV1*C2
         AM(1,4,J)=-YJJL1*ORCV1*C2
         TJM1=P(I,J-1)/RHO(I,J-1)/RUU
         TJJ=P(I,J)/RHO(I,J)/RUU
         DM(1,J)=CD+C2*TJM1-CB*TJJ
         ENDIF
C
C   INVERSE COOLING FLOW
C
         IF(IWALL.EQ.2.AND.IFLOW.EQ.-1)THEN
          IF(I.EQ.IL)THEN
           DM(1,J)= TW1-TJJ
           GOTO 119
          ENDIF
         C1=C1/RJ(I,J)
         C2=C2/RJ(I,J)
         C3=-BIOT/Y(I,J)
         CB=C2-(C1+C3)
         IF(I.LT.IL1) CB=CB-0.5*FLOAT(NORD)*(C1+C3)
         ORCV=1./RHO(I,J)/CV(I,J)
         ORCV1=1./RHO(I,J-1)/CV(I,J-1)
         RUU=RGAS
         TIM1=P(I+1,J)/RHO(I+1,J)/RUU
         CD=-(C1+C3)*TIM1
         IF(I.LT.IL1) THEN
          TIM2=P(I+2,J)/RHO(I+2,J)/RUU
          CD=CD+NORD*(C1+C3)*(-TIM1+0.5*TIM2)
         ENDIF
         BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV*CB
         BM(1,2,J)=-U(I,J)*YJJL*ORCV*CB
         BM(1,3,J)=-V(I,J)*YJJL*ORCV*CB
         BM(1,4,J)=YJJL*ORCV*CB
         AM(1,1,J)=-(-E(I,J-1)*OR+U2V21)*YJJL1*ORCV1*C2
         AM(1,2,J)=U(I,J-1)*YJJL1*ORCV1*C2
         AM(1,3,J)=V(I,J-1)*YJJL1*ORCV1*C2
         AM(1,4,J)=-YJJL1*ORCV1*C2
         TJM1=P(I,J-1)/RHO(I,J-1)/RUU
         TJJ=P(I,J)/RHO(I,J)/RUU
         DM(1,J)=CD+C2*TJM1-CB*TJJ
         ENDIF
C
       ENDIF
 119   CONTINUE
C*
C*  SOLVE 4*4 BLOCK TRIDIAGONAL MATRICS
C*
       CALL NBTRIP(AM,BM,CM,DM,1,JL,4)
```

```
      DO 120 J=1,JL
      DO 120 K=1,4
      DQ(I,J,K)=DM(K,J)
  120 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE FLUXCL
C*
C* SUBROUTINE FOR FLUX VECTOR CALCULATION
C*
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RMi,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >          (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****************************************************************
      DIMENSION A(4,4)
      ENTRY FLUX(II)
      I=II
C*
C* COMPUTE CONVECTIVE TERMS
C*
      DO 10 J=1,JL
C      F(I,J,1)=RHO(I,J)*UN(I,J)/RJ(I,J)*Y(I,J)
C      F(I,J,2)=(  OU(I,J)*UN(I,J)+SAIX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
C      F(I,J,3)=(RHOV(I,J)*UN(I,J)+SAIY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
C      F(I,J,4)=(E(I,J)+P(I,J))*UN(I,J)/RJ(I,J)*Y(I,J)
      CALL AJACOB(1,A,I,J)
      DO 3 K=1,4
      F(I,J,K)=0.
      DO 3 JJ=1,4
 3    F(I,J,K)=F(I,J,K)+A(K,JJ)*Q(I,J,JJ)*Y(I,J)/RJ(I,J)
      G(I,J,1)=RHO(I,J)*VN(I,J)/RJ(I,J)*Y(I,J)
      G(I,J,2)=(RHOU(I,J)*VN(I,J)+ETAX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      G(I,J,3)=(RHOV(I,J)*VN(I,J)+ETAY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      G(I,J,4)=(E(I,J)+P(I,J))*VN(I,J)/RJ(I,J)*Y(I,J)
   10 CONTINUE
      RETURN
C*
C*  E MINUS FLUX VECTOR
C*
      ENTRY FLUXM(II)
```

```
      I=II
      DO 20 J=1,JL
      CALL AJACOB(2,A,I,J)
      DO 17 K=1,4
      G(I,J,K)=0.
      DO 17 JJ=1,4
   17 G(I,J,K)=G(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
   20 CONTINUE
      RETURN
C*
C* VISCOUS FLUX VECTOR
C*
      ENTRY VFLUX(II)
      I=II
      DO 30 J=2,JL1
      JP1=J+1
      JM1=J-1
      ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
      ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
      IF(PRNT.EQ.0.D0)THEN
      GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
      GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
      GKCPP=ZMUP*GAMP/PRN
      GKCPM=ZMUM*GAMM/PRN
      ELSE
      ZMUTP = 0.5*(ZMUT(JP1)+ZMUT(J))
      ZMUTM = 0.5*(ZMUT(JM1)+ZMUT(J))
      ZMULP = ZMUP - ZMUTP
      ZMULM = ZMUM - ZMUTM
      GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
      GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
      GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
      GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
      ENDIF
      YYP=0.5*(Y(I,J)+Y(I,JP1))
      YYM=0.5*(Y(I,J)+Y(I,JM1))
      YZP=YYP*ZMUP
      YZM=YYM*ZMUM
      AAP1=A1(I,J)*YZP
      AAM1=A1(I,JM1)*YZM
      AAP2=A2(I,J)*YZP
      AAM2=A2(I,JM1)*YZM
      AAP3=A3(I,J)*YZP
      AAM3=A3(I,JM1)*YZM
      AAP4=A4(I,J)*YYP*GKCPP
      AAM4=A4(I,JM1)*YYM*GKCPM
      UP=U(I,JP1)-U(I,J)
      UM=-U(I,JM1)+U(I,J)
      VP=V(I,JP1)-V(I,J)
      VM=V(I,J)-V(I,JM1)
      ERP=E(I,JP1)/RHO(I,JP1)-E(I,J)/RHO(I,J)
      ERM=E(I,J)/RHO(I,J)-E(I,JM1)/RHO(I,JM1)
      U2P=U(I,JP1)**2-U(I,J)**2
      U2M=U(I,J)**2-U(I,JM1)**2
      V2P=V(I,JP1)**2-V(I,J)**2
```

```
      V2M=V(I,J)**2-V(I,JM1)**2
      UVP=U(I,JP1)*V(I,JP1)-U(I,J)*V(I,J)
      UVM=U(I,J)*V(I,J)-U(I,JM1)*V(I,JM1)
      G(I,J,1)=0.
      G(I,J,2)=(AAP1*UP-AAM1*UM)+(AAP2*VP-AAM2*VM)
      G(I,J,3)=(AAP2*UP-AAM2*UM)+(AAP3*VP-AAM3*VM)
      G(I,J,4)=(AAP4*ERP-AAM4*ERM)+0.5*((AAP1-AAP4)*U2P-
     &    (AAM1-AAM4)*U2M)+0.5*((AAP3-AAP4)*V2P-(AAM3-AAM4)*V2M)+
     &    (AAP2*UVP-AAM2*UVM)
C*
C*  INSERT THE EXTRA FIRST ORDER TERMS IN CYLINDRICAL COORDINATE
C*   SYSTEMS
C*
      EYJ=ETAY(I,J)/RJ(I,J)
      EXJ=ETAX(I,J)/RJ(I,J)
      DMUV=0.5*(ZMU(I,JP1)*V(I,JP1)-ZMU(I,JM1)*V(I,JM1))
      DDV =0.5*(V(I,JP1)-V(I,JM1))
      DMUV2=0.5*(ZMU(I,JP1)*V(I,JP1)**2-ZMU(I,JM1)*V(I,JM1)**2)
      DMUUV=0.5*(ZMU(I,JP1)*U(I,JP1)*V(I,JP1)-
     *           ZMU(I,JM1)*U(I,JM1)*V(I,JM1))
      DDU =0.5*(U(I,JP1)-U(I,JM1))
      DDMU=0.5*(ZMU(I,JP1)-ZMU(I,JM1))
      G(I,J,2)=G(I,J,2)-2./3.*EXJ*DMUV
      G(I,J,3)=G(I,J,3)+2./3.*(ZMU(I,J)*EXJ*DDU-V(I,J)*EYJ*DDMU)
      G(I,J,4)=G(I,J,4)-2./3.*(EYJ*DMUV2+EXJ*DMUUV)
   30 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
C **  RIGHT HAND SIDE CALCULATION
C-----------------------------------------------------------------
      SUBROUTINE RHSCL
C ***************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     &             P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     &    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     &  ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     &CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     &,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     &            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     &           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C***************************************************************
      ENTRY RHS(II)
      I=II
      CALL FLUX(I-1)
C       IF((I.NE.2.AND.I.NE.IL1).AND.NORD.EQ.1)CALL FLUX(I-2)
      CALL FLUX(I)
```

```
      EXII=2.*EXI
      EYII=EYI*2.
      DO 10 J=1,JL
      DO 10 K=1,4
 10   DQ(I,J,K)=0.
      J=JL
      JM1=J-1
      IM1=I-1
      DO 20 K=1,4
      DQ(I,J,K)=DQ(I,J,K)+F(I,J,K)-F(I-1,J,K)+
     * CHOI *           G(I,J,K)-G(I,JM1,K)
     CHOI
     >  (3.D0*G(I,J,K)-4.D0*G(I,J-1,K)+G(I,J-2,K))*0.5D0
     CHOI
 20   CONTINUE
      DO 100 J=2,JL1
      JP1=J+1
      JM1=J-1
      DO 100 K=1,4
      IF(I.NE.1)THEN
      DQ(I,J,K)=DQ(I,J,K)+F(I,J,K)-F(I-1,J,K)+
     >            (G(I,JP1,K)-G(I,JM1,K))*0.5
      ELSE
      DQ(I,J,K)=DQ(I,J,K)+0.5*(G(I,JP1,K)-G(I,JM1,K))
      ENDIF
 100  CONTINUE
      IF(I.EQ.IL) GOTO 120
      IF(I.NE.2.AND.I.NE.IL1)THEN
       DO 110 J=1,JL
       DO 110 K=1,4
       DQ(I,J,K)=DQ(I,J,K)+NORD*0.5*(F(I,J,K)-2.*F(I-1,J,K)+
     *                                 F(I-2,J,K))
 110    CONTINUE
      ENDIF
 120  CONTINUE
       IF(I.EQ.IL)GOTO 180
      IP1=I+1
      CALL FLUXM(IP1)
      CALL FLUXM(I)
      IF((I.NE.IL1.AND.I.NE.2).AND.NORD.EQ.1)CALL FLUXM(I+2)
      DO 170 J=2,JL
      DO 170 K=1,4
      DQ(I,J,K)=DQ(I,J,K)+G(IP1,J,K)-G(I,J,K)
      IF(I.NE.IL1.AND.I.NE.2)DQ(I,J,K)=DQ(I,J,K)-NORD*0.5*
     *     (G(I+2,J,K)-2.*G(I+1,J,K)+G(I,J,K))
 170  CONTINUE
 180  CONTINUE
      DO 200 J=2,JL
      DQ(I,J,3)=DQ(I,J,3)-P(I,J)/RJ(I,J)
 200  CONTINUE
      RETURN
C*
C* VISCOUS RIGHT HAND SIDE
C*
      ENTRY VRHS(II)
```

```
      I=II
      CALL VFLUX(I)
      DO 300 J=2,JL1
      DO 300 K=2,4
 300  DQ(I,J,K)=DQ(I,J,K)-G(I,J,K)
      DO 400 J=2,JL
      DQ(I,J,3)=DQ(I,J,3)+4./3.*ZMU(I,J)*V(I,J)/(RJ(I,J)*Y(I,J))
 400  CONTINUE
      RETURN
      END
C ***************************************************************
C     SERVICE SUBROUTINE
C ***************************************************************
      SUBROUTINE SUPPLY
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
     >              P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
     >    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
     > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
     >CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
     >,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
     >            ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >          (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C***************************************************************
      DIMENSION SS(4)
      DATA GO,PATM/9.8067,101325./
      ENTRY CHECK
      DO 10 K=1,4
  10  SS(K)=0.
      DO 20 I=2,IL
      DO 20 J=2,JL
      DO 20 K=1,4
      QQ=Q(I,J,K)
      IF(QQ.EQ.0.D0)GO TO 20
      SS(K)=SS(K)+(DQ(I,J,K)*RJ(I,J)/Y(I,J)/QQ)**2
  20  CONTINUE
      DO 30 K=1,4
  30  SS(K)=DSQRT(SS(K))/(IL*JL)
      WRITE(19,500)NADV,(SS(K),K=1,4)
 500  FORMAT(I5,3X,4(1X,E14.7))
      RETURN
      ENTRY MASS
C
C MASS FLOW RATE
C
      PPI=DARCOS(-1.D0)
      DO 80 I=1,IL
      FLRT=0.
```

```
      DO 75 J=1,JL1
      DELR=DSQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
      CXCY=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCY1=DSQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
      FLRT=FLRT+0.5*PPI*(Y(I,J+1)+Y(I,J))*DELR
     +     *(RHO(I,J+1)*UN(I,J+1)/CXCY1+RHO(I,J)*UN(I,J)/CXCY)
   75 CONTINUE
      WRITE(18,789)I,FLRT
   80 CONTINUE
  789 FORMAT(1X,I8,E14.7)
C
C THRUST AND ISP CALCULATIONS
C
      I=IL
      THRUST=0.
      DO 85 J=1,JL1
      DELR=DSQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
      THRUST=THRUST+0.5*PPI*(Y(I,J+1)+Y(I,J))*DELR*
     >      (RHO(I,J+1)*U(I,J+1)**2+P(I,J+1)-PATM+
     >       RHO(I,J)  *U(I,J)**2+P(I,J)-PATM)
   85 CONTINUE
      CCC=THRUST/FLRT
      SPI=CCC/G0
      WRITE(18,788) THRUST,SPI
  788 FORMAT(//,'*** THRUST=', E14.7,//,'*** ISP =',E14.7)
C
      RETURN
      ENTRY OUTPUT
      WRITE(18,550)NADV
  550 FORMAT(//10(1H*)/'   NADV=',I5//)
      DO 50 I=1,IL
      DO 50 J=1,JL
      ST=(E(I,J)/RHO(I,J)-GM1(I,J)*0.5/GAMMA(I,J)*(U(I,J)**2+
     >    V(I,J)**2))/CV(I,J)
      TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
      RMA=DSQRT((U(I,J)*U(I,J)+V(I,J)*V(I,J))/GAMMA(I,J)
     > *RHO(I,J)/P(I,J))
      SP=P(I,J)*(ST/TT)**(GAMMA(I,J)/GM1(I,J))
      WRITE(18,607)X(I,J),Y(I,J),P(I,J),RMA,TT,V(I,J)
      WRITE(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
  607 FORMAT(6(1X,E14.7))
C     WRITE(6,600)I,J,RHO(I,J),U(I,J),V(I,J),E(I,J),ST
C      WRITE(6,650)P(I,J),UN(I,J),VN(I,J),SP,TT
  600 FORMAT(1X,'#',I2,',',I2,3X,5(1X,E10.3))
  650 FORMAT(10X,5(1X,E10.3))
   50 CONTINUE
C
C WRITE THE LAST TWO LINES
C
C     DO 70 I=IL1,IL
C     DO 70 J=1,JL
C70   WRITE(68) (Q(I,J,K),K=1,4)
C
      RETURN
      END
```

```
C ***************************************************************
C*
C*  LIBRARY SUBROUTINES
C*
      SUBROUTINE NBTRIP(A,B,C,D,ILO,IU,ORDER)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(1),B(1),C(1),D(1),IPS(5),X(5)
      INTEGER ORDER,ORDSQ
      ORDSQ=ORDER**2
      I=ILO
      IOMAT=1+(I-1)*ORDSQ
      IOVEC=1+(I-1)*ORDER
      CALL LUDPVT(B(IOMAT),ORDER,IPS)
      CALL LUSPVT(B(IOMAT),D(IOVEC),D(IOVEC),X,ORDER,IPS)
      DO 100 J=1,ORDER
      IOMATJ=IOMAT+(J-1)*ORDER
      CALL LUSPVT(B(IOMAT),C(IOMATJ),C(IOMATJ),X,ORDER,IPS)
100   CONTINUE
200   CONTINUE
      I=I+1
      IOMAT=1+(I-1)*ORDSQ
      IOVEC=1+(I-1)*ORDER
      I1MAT=IOMAT-ORDSQ
      I1VEC=IOVEC-ORDER
      CALL MULPUT(A(IOMAT),D(I1VEC),D(IOVEC),ORDER)
      DO 300 J=1,ORDER
      IOMATJ=IOMAT+(J-1)*ORDER
      I1MATJ=I1MAT+(J-1)*ORDER
      CALL MULPUT(A(IOMAT),C(I1MATJ),B(IOMATJ),ORDER)
300   CONTINUE
      IF(I.EQ.IU) GO TO 500
      CALL LUDECO(B(IOMAT),ORDER)
      CALL LUSOLV(B(IOMAT),D(IOVEC),D(IOVEC),ORDER)
      DO 400 J=1,ORDER
      IOMATJ=IOMAT+(J-1)*ORDER
      CALL LUSOLV(B(IOMAT),C(IOMATJ),C(IOMATJ),ORDER)
400   CONTINUE
      GO TO 200
500   CONTINUE
      CALL LUDPVT(B(IOMAT),ORDER,IPS)
      CALL LUSPVT(B(IOMAT),D(IOVEC),D(IOVEC),X,ORDER,IPS)
600   CONTINUE
      I=I-1
      IOMAT=1+(I-1)*ORDSQ
      IOVEC=1+(I-1)*ORDER
      I1VEC=IOVEC+ORDER
      CALL MULPUT(C(IOMAT),D(I1VEC),D(IOVEC),ORDER)
      IF(I.GT.ILO) GO TO 600
      RETURN
      END
C-------------------------------------------------------------
      SUBROUTINE LUDPVT(A,ORDER,IPS)
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER ORDER
      DIMENSION A(ORDER,1),IPS(ORDER)
```

```
      DO 5 I=1,ORDER
      IPS(I)=I
    5 CONTINUE
      NM1=ORDER-1
      DO 17 K=1,NM1
      BIG=0.0D0
      DO 11 I=K,ORDER
      IP=IPS(I)
      SIZE=DABS(A(IP,K))
      IF(SIZE-BIG)11,11,10
   10 BIG=SIZE
      IDXPIV=I
   11 CONTINUE
      IF(IDXPIV-K)14,15,14
   14 J=IPS(K)
      IPS(K)=IPS(IDXPIV)
      IPS(IDXPIV)=J
   15 KP=IPS(K)
      PIVOT=A(KP,K)
      KP1=K+1
      DO 16 I=KP1,ORDER
      IP=IPS(I)
      EM=-A(IP,K)/PIVOT
      A(IP,K)=-EM
      DO 16 J=KP1,ORDER
      A(IP,J)=A(IP,J)+EM*A(KP,J)
   16 CONTINUE
   17 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE MULPUT(A,B,C,ORDER)
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER ORDER
      DIMENSION A(1),B(1),C(1)
      DO 200 JR=1,ORDER
      SUM=0.0
      DO 100 JC=1,ORDER
      IA=JR+(JC-1)*ORDER
100   SUM=SUM+A(IA)*B(JC)
200   C(JR)=C(JR)-SUM
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE LUSPVT(A,B,C,X,ORDER,IPS)
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER ORDER
      DIMENSION A(ORDER,1),B(1),C(1),X(1),IPS(1)
      NP1=ORDER+1
      IP=IPS(1)
      X(1)=B(IP)
      DO 2 I=2,ORDER
      IP=IPS(I)
      IM1=I-1
      SUM=0.0D0
```

```
      DO 1 J=1,IM1
    1 SUM=SUM+A(IP,J)*X(J)
    2 X(I)=B(IP)-SUM
      IP=IPS(ORDER)
      C(ORDER)=X(ORDER)/A(IP,ORDER)
      DO 4 IBACK=2,ORDER
      I=NP1-IBACK
      IP=IPS(I)
      IP1=I+1
      SUM=0.0D0
      DO 3 J=IP1,ORDER
    3 SUM=SUM+A(IP,J)*C(J)
    4 C(I)=(X(I)-SUM)/A(IP,I)
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE LUDECO(A,ORDER)
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER ORDER
      DIMENSION A(ORDER,1)
      DO 8 JC=2,ORDER
8     A(1,JC)=A(1,JC)/A(1,1)
      JRJC=1
10    CONTINUE
      JRJC=JRJC+1
      JRJCM1=JRJC-1
      JRJCP1=JRJC+1
      DO 14 JR=JRJC,ORDER
      SUM=A(JR,JRJC)
      DO 12 JM=1,JRJCM1
12    SUM=SUM-A(JR,JM)*A(JM,JRJC)
14    A(JR,JRJC)=SUM
      IF(JRJC.EQ.ORDER) RETURN
      DO 18 JC=JRJCP1,ORDER
      SUM=A(JRJC,JC)
      DO 16 JM=1,JRJCM1
16    SUM=SUM-A(JRJC,JM)*A(JM,JC)
18    A(JRJC,JC)=SUM/A(JRJC,JRJC)
      GO TO 10
      END
C-----------------------------------------------------------------------
      SUBROUTINE LUSOLV(A,B,C,ORDER)
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER ORDER
      DIMENSION A(ORDER,1),B(1),C(1)
      C(1)=C(1)/A(1,1)
      DO 14 JR=2,ORDER
      JRM1=JR-1
      SUM=B(JR)
      DO 12 JM=1,JRM1
12    SUM=SUM-A(JR,JM)*C(JM)
14    C(JR)=SUM/A(JR,JR)
      DO 18 JRJR=2,ORDER
      JR=ORDER-JRJR+1
      JRP1=JR+1
```

```
      SUM=C(JR)
      DO 16 JMJM=JRP1,ORDER
      JM=ORDER-JMJM+JRP1
16    SUM=SUM-A(JR,JM)*C(JM)
18    C(JR)=SUM
      RETURN
      END
C-----------------------------------------------------------------
C     SET ZERO FOR MATRIC (M,M)
      SUBROUTINE SZERO(M,A)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      A(I,J)=0.0D0
   10 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
C  SCALAR*METRIC (M,M)
      SUBROUTINE SMM(M,C,A,B)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      B(I,J)=C*A(I,J)
   10 CONTINUE
      RETURN
      END
C-----------------------------------------------------------------
C  METRIX*METRIX (M*M)
      SUBROUTINE MMM(M,A,B,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M),C(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      C(I,J)=0.0D0
      DO 10 K=1,M
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
   10 CONTINUE
      RETURN
      END
C*****************************************************************
      SUBROUTINE HJAC(A,J)
C*****************************************************************
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(4,4)
      CALL SZERO(4,A)
      A(1,1)=1.D0
      A(2,2)=1.D0
      A(3,3)=1.D0
      A(4,4)=1.D0
      RETURN
      END
C*****************************************************************
```

```
      SUBROUTINE MMV(M,A,B,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M),C(M)
      DO 10 I=1,M
      C(I)=0.DO
      DO 10 K=1,M
      C(I)=C(I)+A(I,K)*B(K)
   10 CONTINUE
      RETURN
      END
C*****************************************************************
      SUBROUTINE INVER(M,A,AINV)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION  A(4,4),B(4,4),AINV(4,4),COF(4,4)
      A11=A(1,1)
      A12=A(1,2)
      A13=A(1,3)
      A14=A(1,4)
      A21=A(2,1)
      A22=A(2,2)
      A23=A(2,3)
      A24=A(2,4)
      A31=A(3,1)
      A32=A(3,2)
      A33=A(3,3)
      A34=A(3,4)
      A41=A(4,1)
      A42=A(4,2)
      A43=A(4,3)
      A44=A(4,4)
      DET=A11*(A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
     > -A23*A32*A44-A22*A43*A34)-
     >    A12*(A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
     > -A23*A31*A44-A21*A43*A34)+
     >    A13*(A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
     > -A22*A31*A44-A21*A42*A34)-
     >    A14*(A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
     > -A22*A31*A43-A21*A42*A33)
      COF(1,1)=A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
     > -A23*A32*A44-A22*A43*A34
      COF(1,2)=-(A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
     > -A23*A31*A44-A21*A43*A34)
      COF(1,3)=A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
     > -A22*A31*A44-A21*A42*A34
      COF(1,4)=-(A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
     > -A22*A31*A43-A21*A42*A33)
      COF(2,1)=-(A12*A33*A44+A13*A34*A42+A14*A32*A43-A14*A33*A42
     > -A13*A32*A44-A12*A43*A34)
      COF(2,2)=A11*A33*A44+A13*A34*A41+A14*A31*A43-A14*A33*A41
     > -A13*A31*A44-A11*A43*A34
      COF(2,3)=-(A11*A32*A44+A12*A34*A41+A14*A31*A42-A14*A32*A41
     > -A12*A31*A44-A11*A42*A34)
      COF(2,4)=A11*A32*A43+A12*A33*A41+A13*A31*A42-A13*A32*A41
     > -A12*A31*A43-A11*A42*A33
      COF(3,1)=A12*A23*A44+A13*A24*A42+A14*A22*A43-A14*A23*A42
```

```
     > -A13*A22*A44-A12*A43*A24
      COF(3,2)=-(A11*A23*A44+A13*A24*A41+A14*A21*A43-A14*A23*A41
     > -A13*A21*A44-A11*A43*A24)
      COF(3,3)=A11*A22*A44+A12*A24*A41+A14*A21*A42-A14*A22*A41
     > -A12*A21*A44-A11*A42*A24
      COF(3,4)=-(A11*A22*A43+A12*A23*A41+A13*A21*A42-A13*A22*A41
     > -A12*A21*A43-A11*A42*A23)
      COF(4,1)=-(A12*A23*A34+A13*A24*A32+A14*A22*A33-A14*A23*A32
     > -A13*A22*A34-A12*A33*A24)
      COF(4,2)=A11*A23*A34+A13*A24*A31+A14*A21*A33-A14*A23*A31
     > -A13*A21*A34-A11*A33*A24
      COF(4,3)=-(A11*A22*A34+A12*A24*A31+A14*A21*A32-A14*A22*A31
     > -A12*A21*A34-A11*A32*A24)
      COF(4,4)=A11*A22*A33+A12*A23*A31+A13*A21*A32-A13*A22*A31
     > -A12*A21*A33-A11*A32*A23
      AINV(1,1)=COF(1,1)/DET
      AINV(1,2)=COF(2,1)/DET
      AINV(1,3)=COF(3,1)/DET
      AINV(1,4)=COF(4,1)/DET
      AINV(2,1)=COF(1,2)/DET
      AINV(2,2)=COF(2,2)/DET
      AINV(2,3)=COF(3,2)/DET
      AINV(2,4)=COF(4,2)/DET
      AINV(3,1)=COF(1,3)/DET
      AINV(3,2)=COF(2,3)/DET
      AINV(3,3)=COF(3,3)/DET
      AINV(3,4)=COF(4,3)/DET
      AINV(4,1)=COF(1,4)/DET
      AINV(4,2)=COF(2,4)/DET
      AINV(4,3)=COF(3,4)/DET
      AINV(4,4)=COF(4,4)/DET
C     CALL MMM(4,A,AINV,B)
C     DO 1 MM=1,4
C     WRITE(6,10) (B(MM,NN),NN=1,4)
C   1 CONTINUE
   10 FORMAT(4D16.7)
      RETURN
      END
C*****************************************************************
      SUBROUTINE CPGAM(CP,CV,GAMMA,GM1,R,I,J,
     >  RHO,RHOU,RHOV,E,TCP)
C*****************************************************************
      PARAMETER(IZ=150,JZ=100)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
     >              ,CPA8,CPA9,CPA10,ENE(101)
C=========
      IF(TCP.NE.0.0) GOTO 20
      UU=RHOU/RHO
      VV=RHOV/RHO
      EE=E/RHO-0.5*(UU**2+VV**2)
      TT=300.0
      IF(EE.LE.ENE(1)) GO TO 20
      DO 10 MM=1,101
        EA= EE - ENE(MM)
```

```
          EB= EE - ENE(MM+1)
          ESIGN= EA*EB
        IF(ESIGN.LE.0.D0)THEN
          T1=300.0+27.611*DFLOAT(MM-1)
          T2=300.0+27.611*DFLOAT(MM)
          TT=(T2*EA-T1*EB)/(EA-EB)
          GO TO 20
        ELSE
        END IF
 10     CONTINUE
        TT=3061.1D0
 20     CONTINUE
        IF(TCP.NE.0.0) TT=TCP
C*
        IF(TT.LE.1000.0)THEN
          CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
          CV=CP-R
        ELSE
          CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
          CV=CP-R
        END IF
        GAMMA=CP/CV
        GM1=GAMMA-1.0
        RETURN
        END
C***************
        SUBROUTINE CPCOEF
C***************
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
       >              ,CPA8,CPA9,CPA10,ENE(101)
        DIMENSION Y(10),A1(10),A2(10),A3(10),A4(10),A5(10)
       >         ,A6(10),A7(10),A8(10),A9(10),A10(10),WM(10)
        DATA RU,WMMIX/8314.3,20.405/
C====================
C CO
        WM(1)=28.010
        Y(1)= 0.13108
C CO2
        WM(2)=44.0
        Y(2)= 0.03636
C H
        WM(3)=1.0
        Y(3)= 0.02387
C H2
        WM(4)=2.0
        Y(4)= 0.15802
C H2O
        WM(5)=18.0
        Y(5)= 0.32366
C NO
        WM(6)=30.0
        Y(6)= 0.00260
C N2
        WM(7)=28.0
```

```
      Y(7)= 0.30407
C O
      WM(8)=16.0
      Y(8)= 0.00158
C OH
      WM(9)=17.0
      Y(9)= 0.01744
C O2
      WM(10)=32.0
      Y(10)= 0.00129
C--------------------------CO
      A1(1)= 0.29840696E+01
      A2(1)= 0.14891390E-02
      A3(1)=-0.57899684E-06
      A4(1)= 0.10364577E-09
      A5(1)=-0.69353550E-14
C
      A6(1)= 0.37100928E+01
      A7(1)=-0.16190964E-02
      A8(1)= 0.36923594E-05
      A9(1)=-0.20319674E-08
      A10(1)= 0.23953344E-12
C--------------------------CO2
      A1(2)= 0.44608041E+01
      A2(2)= 0.30981719E-02
      A3(2)=-0.12392571E-05
      A4(2)= 0.22741325E-09
      A5(2)=-0.15525954E-13
C
      A6(2)= 0.24007797E+01
      A7(2)= 0.87350957E-02
      A8(2)=-0.66070878E-05
      A9(2)= 0.20021861E-08
      A10(2)= 0.63274039E-15
C-------------------------H
      A1(3)= 0.25000000E+01
      A2(3)= 0.00000000
      A3(3)= 0.00000000
      A4(3)= 0.00000000
      A5(3)= 0.00000000
C
      A6(3)= 0.25000000E+01
      A7(3)= 0.00000000
      A8(3)= 0.00000000
      A9(3)= 0.00000000
      A10(3)= 0.00000000
C-------------------------H2
      A1(4)= 0.30558123E+01
      A2(4)= 0.59740400E-03
      A3(4)=-0.16747471E-08
      A4(4)=-0.21247544E-10
      A5(4)= 0.25195487E-14
C
      A6(4)= 0.29432327E+01
      A7(4)= 0.34815509E-02
```

```
      A8(4)=-0.77713819E-05
      A9(4)= 0.74997496E-08
      A10(4)=-0.25203379E-11
C-------------------------H2O
      A1(5)= 0.26340654E+01
      A2(5)= 0.31121899E-02
      A3(5)=-0.90278449E-06
      A4(5)= 0.12673054E-09
      A5(5)=-0.69164732E-14
C
      A6(5)= 0.41675564E+01
      A7(5)=-0.18106868E-02
      A8(5)= 0.59450878E-05
      A9(5)=-0.48670871E-08
      A10(5)= 0.15284144E-11
C-------------------------NO
      A1(6)= 0.31486543E+01
      A2(6)= 0.14151823E-02
      A3(6)=-0.57574881E-06
      A4(6)= 0.10738529E-09
      A5(6)=-0.73900199E-14
C
      A6(6)= 0.42484931E+01
      A7(6)=-0.48661106E-02
      A8(6)= 0.11634155E-04
      A9(6)=-0.99768494E-08
      A10(6)= 0.30483948E-11
C-------------------------N2
      A1(7)= 0.28536374E+01
      A2(7)= 0.16014368E-02
      A3(7)=-0.62888336E-06
      A4(7)= 0.11428932E-09
      A5(7)=-0.77953822E-14
C
      A6(7)= 0.37034288E+01
      A7(7)=-0.14179405E-02
      A8(7)= 0.28625094E-05
      A9(7)=-0.12018374E-08
      A10(7)=-0.13475522E-13
C-------------------------O
      A1(8)= 0.25342961E+01
      A2(8)=-0.12478170E-04
      A3(8)=-0.12562724E-07
      A4(8)= 0.69029862E-11
      A5(8)=-0.63797095E-15
C
      A6(8)= 0.30309401E+01
      A7(8)=-0.22525853E-02
      A8(8)= 0.39824540E-05
      A9(8)=-0.32604921E-08
      A10(8)= 0.10152035E-11
C-------------------------OH
      A1(9)= 0.28897814E+01
      A2(9)= 0.10005879E-02
      A3(9)=-0.22048807E-06
```

```
      A4(9)= 0.20191288E-10
      A5(9)=-0.39409831E-15
C
      A6(9)= 0.38737300E+01
      A7(9)=-0.13393772E-02
      A8(9)= 0.16348351E-05
      A9(9)=-0.52133639E-09
      A10(9)= 0.41826974E-13
C-------------------------02
      A1(10)= 0.36122139E+01
      A2(10)= 0.74853166E-03
      A3(10)=-0.19820647E-06
      A4(10)= 0.33749008E-10
      A5(10)=-0.23907374E-14
C
      A6(10)= 0.37837135E+01
      A7(10)=-0.30233634E-02
      A8(10)= 0.99492751E-05
      A9(10)=-0.98189101E-08
      A10(10)= 0.33031825E-11
C================================
      CPA1=0.D0
      CPA2=0.D0
      CPA3=0.D0
      CPA4=0.D0
      CPA5=0.D0
      CPA6=0.D0
      CPA7=0.D0
      CPA8=0.D0
      CPA9=0.D0
      CPA10=0.D0
      DO 10 J=1,10
      CPA1=CPA1+Y(J)*A1(J)*RU/WMMIX
      CPA2=CPA2+Y(J)*A2(J)*RU/WMMIX
      CPA3=CPA3+Y(J)*A3(J)*RU/WMMIX
      CPA4=CPA4+Y(J)*A4(J)*RU/WMMIX
      CPA5=CPA5+Y(J)*A5(J)*RU/WMMIX
      CPA6=CPA6+Y(J)*A6(J)*RU/WMMIX
      CPA7=CPA7+Y(J)*A7(J)*RU/WMMIX
      CPA8=CPA8+Y(J)*A8(J)*RU/WMMIX
      CPA9=CPA9+Y(J)*A9(J)*RU/WMMIX
      CPA10=CPA10+Y(J)*A10(J)*RU/WMMIX
  10  CONTINUE
C...
      R=RU/WMMIX
      DO 20 MM=1,101
      TT=300.0+27.611*DFLOAT(MM-1)
      IF(TT.LE.1000.0)THEN
        CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
        CV=CP-R
        ENE(MM)=CV*TT
      ELSE
        CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
        CV=CP-R
        ENE(MM)=CV*TT
```

```
      END IF
 20   CONTINUE
      RETURN
      END
//DATA.INPUT DD *
&INPUT IL=135,JL=80,NBEG=1,NEND=1,NITER=1,PO=1 D+06, TO=3061.1DO,
  CFL1=0.5D+04,CFL=100.,OMEGAX=0.,OMEGAY=0.5,RM1=1.2,RM2=4.0,NORD=1,
       AIN=0.05,AEX=.236,RL=.695,THETA=1.0,CPO=7152.4853,GAMMAO=1.17,
    ITIME=1,IREAD=1,FST=0.00,TWALL=3000.,FSTY=0.9,PB=0.,PRNT=0.7,
       IVISC=1,IWALL=0,PRN=0.7,REN=1.D5,TREF=3000.,ZMUO=8.5D-03,
      IWBC=1 BIOT=15.,TW1=500.,IFLOW=1
&END
//DATA.FT38F001 DD DSN=STU.I19500.MYH100.HERMES.DIF.H135M80.VIS,
//      DISP=(OLD,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT66F001 DD DSN=STU.I19500.MYH100.HERMES2.DIF.RERUN.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT19F001 DD DSN=STU.I19500.MYH100.HERMES2.DIF.DQ.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT18F001 DD DSN=STU.I19500.MYH100.HERMES2.DIF.SOLU.VIS,
//      DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=FB,LRECL=130,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
//DATA.FT68F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.LINE.VIS,
//      DISP=(OLD,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
//      DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
//      SPACE=(TRK,(9,5),RLSE)
// EXEC PROMPTME
```

X14140

USERID: V19 ORIGIN: PSUVM CREATED: 06/20/89 15:48:19

FILENAME: NPROG11 FOR CLASS: A FORMAT:J

SPOOLID: 2822 RECS: 3707 COPY: 1 DUPLICATE: 1

PRINTED AT: PSUVM ID: $PPCBP01 AT: 06/20/89 15:48:27

```
*************************************************************
*
* THIS FILE WAS SENT BY THE COMMAND:
* PRT3812  NPROG11 FOR A1 ( PPCB1 COPIES 1 ORIENT N FONT 11
*
*************************************************************
```

```
      PROGRAM NOZZLE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     >        TAPE1,TAPE2,TAPE3,TAPE4,TAPE7,TAPE8,TAPE9,TAPE10,
     >        TAPE11,TAPE12)
*************************************************************
*     PROGRAM NAME: NOZZLE                                  *
*     AXISYMMETRIC SUPERSONIC NOZZLE FLOW                   *
*     IN GENERAL COORDINATE SYSTEM                          *
*     USING TIME ITERATIVE UW/CD DDADI METHOD               *
*     WITH THIN-LAYER APPROXIMATED NAVIER-STOKES' EQS.      *
*************************************************************
*
*     MAIN PROGRAM
*
*****************************************************************
*     TAPE1 - READ NAMELIST /INPUT/
*     TAPE2 - WRITE NAMELIST /INPUT/
*     TAPE3 - READ X(I,J), Y(I,J)
*     TAPE4 - WRITE FLRT
*     TAPE5 - READ INPUT DATA
*     TAPE6 - WRITE OUTPUT DATA
*     TAPE7 - READ DELTAU(I,J), Q(I,J,K)
*     TAPE8 - WRITE DELTAU(I,J), Q(I,J,K)
*     TAPE9 - READ NEND, SS(K) (=DQ/Q)
*     TAPE10 - WRITE NEND, SS(K) (=DQ/Q)
*     TAPE11 - READ NAMELIST /DINPL/
*     TAPE12 - WRITE NAMELIST /DINPL/
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
     >        P0,T0,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
*****************************************************************
      CALL INITIA
      WRITE (6,500)
  500 FORMAT(1H1//)
      DO 10 NADV=NBEG,NEND
      CALL SOLVE
      CALL CHECK
```

```
  10 CONTINUE
     WRITE (6,500)
     CALL MASS
     WRITE (6,500)
     CALL OUTPUT
     STOP
     END
     SUBROUTINE INITIA
*****************************************************************
*
*     SET UP INITIAL CONDITIONS
*
*****************************************************************
     PARAMETER (IZ=60,JZ=40)
     COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
    >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
    >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
    >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
     COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
    >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
    >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
    >        A4(IZ,JZ)
     COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
    >        RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
    >        P0,T0,TWALL,PB,SUM(4)
     COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
    >        IVISC,IWALL,IWRT
     COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
    >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
    >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
    >              X7(9),Y7(9),F7(9,9)
     DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
     EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
    >           (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
     DIMENSION SS(4)
     NAMELIST /INPUT/ IL,JL,NBEG,NEND,NITER,THETA,NORD,CFL,CFL1,
    >         ITIME,OMEGAX,OMEGAY,AIN,AEX,RL,FST,FSTY,RM1,RM2,
    >         IVISC,IWALL,RG,AMW0,GAMMA0,CP,REN,PRN,PRNT,TREF,
    >         ZMU0,OMEGA,P0,T0,TWALL,PB,IREAD,IWRT,IRUN
     NAMELIST /DINPL/ X1,Y1,F1,X2,Y2,F2,X3,Y3,F3,
    >                 X4,Y4,F4,X5,Y5,F5,X6,Y6,F6,
    >                 X7,Y7,F7
*****************************************************************
*
*     IF THE DIMENSION IN COMMON BLOCK MUST BE CHANGED
*     PLEASE CHANGE THE PARAMETER STATEMENT
*
... IL=TOTAL GRID NUMBER IN XI DIRECTION
... JL=TOTAL GRID NUMBER IN ETA DIRECTION
... NBEG=COUNTING INDEX OF ITERATION STEP
        =1 FOR THE FIRST RUN
        =ANY NUMBER EXCEPT 1 FOR RERUN
... NEND=NUMBER OF ITERATIONS FOR THE FIRST RUN ONLY
... NITER=NUMBER IF ITERATIONS TO BE RUN WHEN RERUN (NBEG.NE.1)
... THETA=ALWAYS EQUALS 1
```

```
... NORD=IN USE IN PNS, NOT IN USE IN TLNS
... CFL=CFL NUMBER
... CFL1=CFL NUMBER FOR PNS MARCHING
... ITIME=0 FOR CONSTANT DT
         =1 FOR CONSTANT CFL
... OMEGAX=ARTIFICIAL DISSIPATION CONSTANT IN XI DIRECTION
... OMEGAY=ARTIFICIAL DISSIPATION CONSTANT IN ETA DIRECTION
... AIN=THE INLET RADIUS FOR CONICAL NOZZLE (IGNORED IN IREAD=1)
... AEX=THE EXIT RADIUS FOR CONICAL NOZZLE (IGNORED IF IREAD=1)
... RL=TOTAL LENGTH OF CONICAL NOZZLE (IGNORED IF IREAD=1)
... FST=STRETCHING FACTOR IN XI DIRECTIO (0 FOR UNIFORM GRID)
       (IGNORED IN IREAD=1) (NOT IN USE IN TLNS)
... FSTY=STRETCHING FACTOR IN ETA DIRECTION (0 FOR UNIFORM GRID)
         (IGNORED IN IREAD=1) (NOT IN USE IN TLNS)
... RM1=THE INITIAL GUESS FOR INLET MACH NUMBER
       (IGNORED IN IREAD=1)
... RM2=THE INITIAL GUESS FOR EXIT MACH NUMBER
       (IGNORED IN IREAD=1)
... IVISC=0 INVISCID FLOW
         =1 VISCOUS FLOW
... IWALL=0 FOR ADIABATIC WALL
         =1 FOR CONSTANT WALL TEMPERATURE
... RG=UNIVERSAL GAS CONSTANT (NOT IN USE IN PNS SOLUTION)
... AMW0=MOLECULAR WEIGHT IN STAGNATION CHAMBER
         (NOT IN USE IN PNS)
... GAMMA0=SPECIFIC HEAT RATIO (STAGNATION CHAMBER VALUE WHEN
        USED FOR REAL GASES IN TLNS)
... CP=CONSTANT PRESSURE SPECIFIC HEAT (NOT IN USE IN TLNS)
... REN=REYNOLDS NUMBER
         (CAN BE SWITCH ON OR OFF IN THIS SUBROUTINE)
... PRN=PRANDTL NUMBER
... PRNT=TURBULENT PRANDTL NUMBER
         =0. FOR LAMINAR FLOW
         =0.9 FOR TURBULENT FLOW
... TREF=THE REFERENCE TEMPERATURE FOR VISCOSITY CALCULATION
... ZMU0=THE VISCOSITY AT T=TREF
... OMEGA=EXPONENTIAL VISCOSITY LAW
... P0=STAGNATION PRESSURE
... T0=STAGNATION TEMPERATURE
... TWALL=GIVEN WALL TEMPERATURE FOR IWALL=1
... PB=THE BACK PRESSURE AT THE EXIT OF NOZZLE
      =0. (SUBSONIC FLOW EXTRAPOLATED FROM INTERIOR)
      =THE SPECIFIED BACK PRESSURE (FIXED THE PRESSURE FOR
       SUBSONIC PORTION AT EXIT)
... IREAD=0 FOR DEFAULT CONICAL NOZZLE
         =1 READ GRID FROM DATA FILE
... IWRT=1  PRINTING OF FLOWFIELD RESULTS
        =0 NO PRINTING OF FLOWFIELD RESULTS
... IRUN=0 FOR 1ST RUN
*
*     READ INPUT DATA
*
      READ (1,INPUT)
      READ (11,DINPL)
      IRUN=IRUN+1
```

```
      IL1=IL-1
      JL1=JL-1
*
*     READ GRID FROM DATA FILE
*
      IF(IREAD.EQ.1) THEN
        READ (3,501) ((X(I,J),Y(I,J),I=1,IL),J=1,JL)
 501    FORMAT(E17.9,4E16.9)
      ELSE
      END IF
*
*     COORDINATE TRANSFORMATION
*
      EXI=1.0
      EYI=1.0
      DO 30 I=1,IL
      IP1=I+1
      IM1=I-1
      IF(I.EQ.1) IM1=1
      IF(I.EQ.IL) IP1=IL
      DSAI=2.*EXI
      IF(I.EQ.1.OR.I.EQ.IL) DSAI=EXI
      DO 30 J=1,JL
      JP1=J+1
      JM1=J-1
      IF(J.EQ.1) JM1=1
      IF(J.EQ.JL) JP1=JL
      DETA=2.*EYI
      IF(J.EQ.1.OR.J.EQ.JL) DETA=EYI
      XSAI=(X(IP1,J)-X(IM1,J))/DSAI
      YSAI=(Y(IP1,J)-Y(IM1,J))/DSAI
      XETA=(X(I,JP1)-X(I,JM1))/DETA
      YETA=(Y(I,JP1)-Y(I,JM1))/DETA
      IF(J.EQ.1) THEN
        XETA=XETA-0.5*(X(I,J)-2.*X(I,J+1)+X(I,J+2))
        YETA=YETA-0.5*(Y(I,J)-2.*Y(I,J+1)+Y(I,J+2))
      ELSE
      END IF
*
*     JACOBIAN IS DEFINED AS -
*
*                              -1
*     J=(X   *Y   -X   *Y   )
*         SAI  ETA  ETA  SAI
*
      RJP=XSAI*YETA-XETA*YSAI
      RJ(I,J)=1./RJP
      SAIX(I,J)=YETA/RJP
      SAIY(I,J)=-XETA/RJP
      ETAX(I,J)=-YSAI/RJP
      ETAY(I,J)=XSAI/RJP
   30 CONTINUE
*
*     CALCULATE METRIC TERMS AT MID POINTS
*
```

```
      CALL MCONST
*
*     INITIALIZATION - COMPUTE Q(I,J,K)
*
*
*     GIVE THE INITIAL VALUE OF VISCOSTY
*     IF THE VISCOSITY AT T=TREF IS GIVEN FROM INPUT
*     THE CALCULATION FOR ZMUO MUST BE SWITCHED OFF
*
      GM1=GAMMA0-1.
      R=RG/AMW0
      CV=CP/GAMMA0
      TIN=T0/(1.+0.5*GM1*RM1**2)
      UIN=RM1*SQRT(GAMMA0*R*TIN)
      PIN=P0*(TIN/T0)**(GAMMA0/GM1)
      RIN=PIN/(R*TIN)
      ZMU0=(RIN*UIN*Y(1)*2.)/REN
*
*     SKIP TO RERUN THE CODE
*
      IF(IRUN.NE.1) GO TO 100
      DO 40 I=1,IL
      IF(I.EQ.1) THEN
        AMWS=AMW0
        GAMMA=GAMMA0
        GM1=GAMMA-1.
        R0=P0/(RG/AMWS)/T0
      END IF
   42 RM=RM1+FLOAT(I-1)/FLOAT(IL1)*(RM2-RM1)
      GMM=1.+0.5*GM1*RM**2
      TS=T0/GMM
      PS=P0/GMM**(GAMMA/GM1)
      RS=PS/(RG/AMWS)/TS
      IF(I.EQ.1) THEN
        WRITE (6,504) TS,PS,RS,AMWS,GAMMA
  504   FORMAT(//1X,'  TS=',E11.5,'  PS=',E11.5,'  RS=',E11.5,
     >         16X,             '  AMW=',E11.5,'  GAMMA=',E11.5)
   41   TS1=TS
        PS1=PS
        RS1=RS
        ES=FE(RS,TS)
        AMWS=FAMW(RS,TS)
        GAMMA=1.+(RG/AMWS)/(ES/TS)
        GM1=GAMMA-1
        GMM=1.+0.5*GM1*RM**2
        TS=T0/GMM
        PS=P0/GMM**(GAMMA/GM1)
        RS=PS/(RG/AMWS)/TS
        WRITE (6,503) TS,PS,RS,ES,AMWS,GAMMA
  503   FORMAT(1X,'  TS=',E11.5,'  PS=',E11.5,'  RS=',E11.5,
     >         '  ES=',E11.5,'  AMW=',E11.5,'  GAMMA=',E11.5)
        IF(ABS(TS-TS1).GT.1.E-5.OR.ABS(PS-PS1).GT.1.E-5.OR.
     >     ABS(RS-RS1).GT.1.E-5) GO TO 41
      END IF
      ES=FE(RS,TS)
```

```
      CO=SQRT(FCO2(PS,RS,TS,ES,AMWS))
      UU=RM*CO
      DO 40 J=1,JL
      IF(I.EQ.1.OR.I.EQ.IL) THEN
        IF(I.EQ.1) SLOPE=(Y(I+1,J)-Y(I,J))/(X(I+1,J)-X(I,J))
        IF(I.EQ.IL) SLOPE=(Y(I,J)-Y(I-1,J))/(X(I,J)-X(I-1,J))
      ELSE
        SLOPE=(Y(I+1,J)-Y(I-1,J))/(X(I+1,J)-X(I-1,J))
      END IF
      DENOM=SQRT(1.+SLOPE*SLOPE)
      U(I,J)=UU/DENOM
      V(I,J)=UU*SLOPE/DENOM
      UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
      VN(I,J)=ETAX(I,J)*U(I,J)+ETAY(I,J)*V(I,J)
*
*     SLIP INITIAL CONDITION, IVISC=0
*
      IF(J.EQ.JL.AND.IVISC.EQ.0) THEN
        U(I,J)=UU/DENOM
        V(I,J)=-ETAX(I,J)/ETAY(I,J)*U(I,J)
        UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
        VN(I,J)=0.
      END IF
*
*     NO-SLIP INITIAL CONDITION, IVISC=1
*
      IF(J.EQ.JL.AND.IVISC.EQ.1) THEN
        U(I,J)=0.
        V(I,J)=0.
        UN(I,J)=0.
        VN(I,J)=0.
      END IF
      AMW(I,J)=AMWS
      E(I,J)=ES
      T(I,J)=TS
      P(I,J)=P0/(T0/T(I,J))**(GAMMA/GM1)
      IF(J.EQ.JL.AND.IVISC.EQ.1) THEN
        IF(IWALL.EQ.1) T(I,J)=TWALL
        P(I,J)=P(I,J-1)
        IF(I.EQ.IL.AND.PB.NE.0.0) P(I,J)=PB
      ELSE
      END IF
      RHO(I,J)=P(I,J)/(RG/AMW(I,J))/T(I,J)
      RHOU(I,J)=RHO(I,J)*U(I,J)
      RHOV(I,J)=RHO(I,J)*V(I,J)
      E0(I,J)=RHO(I,J)*(E(I,J)+0.5*(U(I,J)**2+V(I,J)**2))
   40 CONTINUE
*
*     INITIALIZATION - COMPUTE DELTAU(I,J)
*
      EIGMAX=0.
      DO 50 I=1,IL
      DO 50 J=1,JL
      CO=SQRT(FCO2(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J)))
      CX=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
```

```
      CY=SQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*CO)/EXI
      CY=(VN(I,J)+CY*CO)/EYI
      EIGNN=ABS(CX)
      IF(EIGNN.LE.ABS(CY)) EIGNN=ABS(CY)
      IF(ITIME.EQ.1) GO TO 55
      IF(CX.GE.EIGMAX) EIGMAX=CX
      IF(CY.GT.EIGMAX) EIGMAX=CY
   55 DELTAU(I,J)=CFL/EIGNN
   50 CONTINUE
      WRITE (6,INPUT)
      WRITE (2,INPUT)
      WRITE (6,DINPL)
      IF(ITIME.EQ.1) RETURN
      DO 60 I=1,IL
      DO 60 J=1,JL
      DELTAU(I,J)=CFL/EIGMAX
   60 CONTINUE
      RETURN
  100 CONTINUE
*
*     READ FLOWFIELD DATA, (NBEG, NEND ARE DETERMIND BY NDUM)
*
   70 READ (9,502,END=65) NDUM,(SS(K),K=1,4)
  502 FORMAT(I5,3X,4(1X,E14.7))
      WRITE (10,502) NDUM,(SS(K),K=1,4)
      GO TO 70
   65 CONTINUE
      NBEG=NDUM+1
      NEND=NBEG+NITER-1
      READ (7) ((DELTAU(I,J),I=1,IL),J=1,JL)
      READ (7) ((RHO(I,J),RHOU(I,J),RHOV(I,J),EO(I,J),
     >     I=1,IL),J=1,JL)
      DO 80 I=1,IL
      DO 80 J=1,JL
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      E(I,J)=EO(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2)
      T(I,J)=FT(RHO(I,J),E(I,J))
      AMW(I,J)=FAMW(RHO(I,J),T(I,J))
      P(I,J)=RHO(I,J)*(RG/AMW(I,J))*T(I,J)
   80 CONTINUE
*
*     CHANGES IN /INPUT/ PUT HERE AND ADD - WRITE (2,INPUT)
*
      WRITE (6,INPUT)
      WRITE (6,DINPL)
      RETURN
      END
      SUBROUTINE SOLVE
*****************************************************************
*
*     SOLVE SUBROUTINE
```

```
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
     >        PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
*****************************************************************
      JEND=JL
      IF(IVISC.EQ.1) JEND=JL1
*
*     FORWARD SWEEP
*
*
*     RHS CALCULATIONS
*
      DO 20 I=2,IL
      CALL RHSEF(I)
      IF(IVISC.EQ.1) THEN
        CALL MULAM(I)
        IF(PRNT.NE.0.0) CALL MUTUR(I)
        CALL KLAM(I)
        IF(PRNT.NE.0.0) CALL KTUR(I)
        CALL RHSVS(I)
      END IF
      CALL RHSH(I)
*
*     CALCULATE RESIDUAL
*
      DO 20 J=1,JL
      DO 20 K=1,4
      DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
   20 CONTINUE
*
*     ADD SAI DIRECTION 4TH ORDER ARITFICIAL VISCOSITY
*
      IF(OMEGAX.NE.0.0) CALL ADDX
*
*     ADD ETA DIRECTION 4TH ORDER ARITFICIAL VISCOSITY
*
      IF(OMEGAY.NE.0.0) CALL ADDY
      DO 30 I=2,IL
*
```

```
*     SOLVE L-ETA OPERATOR
*
      CALL COEFY(I)
*
*     UPDATE VARIABLES FORWARD SWEEPT
*
      DO 40 J=2,JEND
      RJJ=RJ(I,J)/Y(I,J)
      DO 45 K=1,4
      Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
   45 CONTINUE
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+ETAY(I,J)*V(I,J)
      E(I,J)=EO(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2)
      T(I,J)=FT(RHO(I,J),E(I,J))
      AMW(I,J)=FAMW(RHO(I,J),T(I,J))
      P(I,J)=RHO(I,J)*(RG/AMW(I,J))*T(I,J)
   40 CONTINUE
        CALL MULAM(I)
*     CENTERLINE BOUNDARY CONDITIONS
*
      CALL CLBC(I)
*
*     WALL BOUNDARY CONDITIONS
*
      IF(IVISC.EQ.1) CALL WALLBC(I)
   30 CONTINUE
*
*     BACKWARD SWEEPT
*
*
*     RHS CALCULATIONS
*
      DO 70 IB=2,IL1
      I=IL1-IB+2
      CALL RHSEF(I)
      IF(IVISC.EQ.1) THEN
        CALL MULAM(I)
        IF(PRNT.NE.0.0) CALL MUTUR(I)
        CALL KLAM(I)
        IF(PRNT.NE.0.0) CALL KTUR(I)
        CALL RHSVS(I)
      END IF
      CALL RHSH(I)
*
*     CALCULATE RESIDUAL
*
      DO 70 J=1,JL
      DO 70 K=1,4
      DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
   70 CONTINUE
*
*     ADD SAI DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
```

```
*
      IF(OMEGAX.NE.0.0) CALL ADDX
*
*     ADD ETA DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
*
      IF(OMEGAY.NE.0.0) CALL ADDY
      DO 80 IB=2,IL1
      I=IL1-IB+2
*
*     SOLVE L-ETA OPERATOR
*
      CALL COEFY(I)
*
*     UPDATING VARIABLES BACKWARD SWEEP
*
      DO 90 J=2,JEND
      RJJ=RJ(I,J)/Y(I,J)
      DO 95 K=1,4
      Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
   95 CONTINUE
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      E(I,J)=E0(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2)
      T(I,J)=FT(RHO(I,J),E(I,J))
      AMW(I,J)=FAMW(RHO(I,J),T(I,J))
      P(I,J)=RHO(I,J)*(RG/AMW(I,J))*T(I,J)
*
*     UPDATING DELTAU(I,J)
*
      CO=SQRT(FCO2(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J)))
      CX=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CY=SQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*CO)
      CY=(VN(I,J)+CY*CO)
      EIGNN=ABS(CX)
      IF(EIGNN.LE.ABS(CY)) EIGNN=ABS(CY)
      DELTAU(I,J)=ITIME*CFL/EIGNN+(1-ITIME)*DELTAU(I,J)
   90 CONTINUE
*
*     CENTERLINE BOUNDARY CONDITIONS
*
      CALL CLBC(I)
*
*     WALL BOUNDARY CONDITIONS
*
      IF(IVISC.EQ.1) CALL WALLBC(I)
   80 CONTINUE
      RETURN
      END
      SUBROUTINE COEFY(I)
*****************************************************************
*
*     SETTING COEFFICIENTS FOR LY-OPERATOR
```

```
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
     >        PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
      DIMENSION IN(4),EE(4,4,JZ),EL(4,JZ),W(4,JZ)
      DIMENSION AM(4,4),BM(4,4),CM(4,4),DM(4)
      DIMENSION AL(4,4),BE(4),DTEMP(4),ISUB(JZ)
      DIMENSION B(4,4),BL1(4,4),D(4,4),A(4,4),AJM(4,4)
      DATA ISUB /JZ*0/
*****************************************************************
*
*     CHECK THE SONIC POINT AT DOWNSTREAM END
*
      IF(IVISC.NE.1) GO TO 5
      IF(I.NE.IL) GO TO 5
      DO 10 J=1,JL
      CO=SQRT(FCO2(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J)))
      CONTRA=UN(I,J)-SQRT(SAIX(I,J)**2+SAIY(I,J)**2)*CO
      IF(CONTRA.LT.0.0) THEN
        ISUB(J)=1
      ELSE
        ISUB(J)=0
      END IF
      IF(PB.EQ.0.0) ISUB(J)=0
   10 CONTINUE
    5 CONTINUE
*
*     ON THE CENTER LINE OF THE NOZZLE AT J=1
*
      J=1
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      DO 15 M=1,4
      DM(M)=0.
      BM(M,M)=BM(M,M)+1.0
   15 CONTINUE
      CALL SZERO(4,CM)
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
*
*     INTERIOR NODS
```

```
*
      DO 20 J=2,JL1
      TAUD=0.50*DELTAU(I,J)*THETA/EYI
      TAUD2=2.*TAUD
      JM1=J-1
      JP1=J+1
      CALL JCBAB(2,0,B,I,JM1)
      CALL SMM(4,TAUD,B,AM)
      CALL SZERO(4,BM)
      DO 25 M=1,4
      BM(M,M)=BM(M,M)+1.
   25 CONTINUE
      CALL JCBABPM(1,1,0,A,I,J)
      CALL JCBABPM(1,2,0,AJM,I,J)
      CALL JCBD(D,I,J)
      DO 30 M=1,4
      DO 30 N=1,4
      BM(M,N)=BM(M,N)-TAUD2*(D(M,N)-A(M,N)+AJM(M,N))
   30 CONTINUE
      CALL JCBAB(2,0,B,I,JP1)
      CALL SMM(4,-TAUD,B,CM)
*
*     INSERT VISCOUS JACOBIAN LHS HERE
*
      IF(IVISC.EQ.1) THEN
        CALL JCBMVS(A,B,D,I,J)
        DO 35 M=1,4
        DO 35 N=1,4
        AM(M,N)=AM(M,N)-DELTAU(I,J)*A(M,N)
        BM(M,N)=BM(M,N)+DELTAU(I,J)*B(M,N)
        CM(M,N)=CM(M,N)-DELTAU(I,J)*D(M,N)
   35   CONTINUE
      ELSE
      END IF
      DO 40 K=1,4
      DM(K)=DQ(I,J,K)
   40 CONTINUE
*
*     DOWNSTREAM BOUNDARY CONDITIONS FOR VISCOUS FLOW
*
      IF(IVISC.EQ.1.AND.(I.EQ.IL.AND.ISUB(J).EQ.1)) THEN
        CALL TMPM(1,0,BL1,I,J)
        DO 45 K=1,4
        BL1(4,K)=0.
   45   CONTINUE
        CALL MMM(4,BL1,AM,A)
        CALL MMM(4,BL1,BM,B)
        CALL MMM(4,BL1,CM,D)
        DO 50 M=1,4
        DO 50 N=1,4
        AM(M,N)=A(M,N)
        BM(M,N)=B(M,N)
        CM(M,N)=D(M,N)
   50   CONTINUE
        DO 55 M=1,4
```

```
      DTEMP(M)=0.
      DO 55 K=1,4
      DTEMP(M)=DTEMP(M)+BL1(M,K)*DM(K)
   55 CONTINUE
      DO 60 M=1,4
      DM(M)=DTEMP(M)
   60 CONTINUE
      AR=FAR(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))
      AE=FAE(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))
      AER=AE/RHO(I,J)
      DPDR=AR+AER*(-E0(I,J)/RHO(I,J)+(U(I,J)**2+V(I,J)**2))
      DPDU=-AER*U(I,J)
      DPDV=-AER*V(I,J)
      DPDE=AER
      BM(4,1)=DPDR/Y(I,J)
      BM(4,2)=DPDU/Y(I,J)
      BM(4,3)=DPDV/Y(I,J)
      BM(4,4)=DPDE/Y(I,J)
      IF(PB.NE.0.0) THEN
        DM(4)=(PB-P(I,J))/RJ(I,J)
      ELSE
        DM(4)=0.
      END IF
    ELSE
    END IF
    CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
 20 CONTINUE
*
*     WALL  BOUNDARY CONDITIONS FOR INVISCID FLOW, EULER EQS.
*
    J=JL
    TAUD=THETA*DELTAU(I,J)/EYI
    IF(IVISC.EQ.1) GO TO 65
    CALL SZERO(4,AM)
    CALL JCBAB(2,0,B,I,J-1)
    CALL JCBABPM(1,1,0,A,I,J)
    CALL JCBABPM(1,2,0,AJM,I,J)
    CALL TMPM(2,0,BL1,I,J)
    DO 70 M=1,3
    DO 70 N=1,4
    DO 70 K=1,4
    AM(M,N)=AM(M,N)+TAUD*BL1(M,K)*B(K,N)
 70 CONTINUE
    CALL SZERO(4,BM)
    CALL JCBAB(2,0,B,I,J)
    CALL JCBD(D,I,J)
    DO 75 M=1,3
    DO 75 N=1,4
    BM(M,N)=BM(M,N)+BL1(M,N)
    DO 75 K=1,4
    BM(M,N)=BM(M,N)
   >       +TAUD*BL1(M,K)*(B(K,N)+A(K,N)-D(K,N)-AJM(K,N))
 75 CONTINUE
    BM(4,1)=-VN(I,J)
    BM(4,2)=ETAX(I,J)
```

```
      BM(4,3)=ETAY(I,J)
      BM(4,4)=0.
      CALL SZERO(4,CM)
      DO 80 M=1,3
      DM(M)=0.
      DO 80 K=1,4
      DM(M)=DM(M)+BL1(M,K)*DQ(I,J,K)
   80 CONTINUE
      DM(4)=0.
      GO TO 85
   65 CONTINUE
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      CALL SZERO(4,CM)
      DO 90 M=1,4
      DM(M)=0.
   90 BM(M,M)=1.0
   85 CONTINUE
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
*
*     SOLVE 4*4 BLOCK TRIDIAGONAL MATRICS
*
      CALL SOLU(W,JL,4,EE,EL)
      DO 95 J=1,JL
      DO 95 K=1,4
      DQ(I,J,K)=W(K,J)
   95 CONTINUE
      RETURN
      END
      SUBROUTINE BC
************************************************************************
*
*     SUBROUTINE FOR BOUNDARY CONDITIONS
*
************************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
     >        PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
************************************************************************
      ENTRY CLBC(II)
************************************************************************
```

```
*
*    CENTER LINE BOUNDARY CONDITIONS
*
      I=II
*
*     THE QUANTITIES EXTRAPOLATED ARE U, RHO, E0 AND LET V=0
*
      SY=SAIY(I,1)
      EY=ETAY(I,1)
      DENOM=SY-1.5*EY
      IF(I.EQ.1) THEN
        UIM1=0.
        RHOIM1=0.
        E0IM1=0.
      ELSE
        UIM1=U(I-1,1)
        RHOIM1=RHO(I-1,1)
        E0IM1=E0(I-1,1)
      END IF
      U(I,1)=(SY*UIM1-0.5*EY*(4.*U(I,2)-U(I,3)))/DENOM
      V(I,1)=0.
      UN(I,1)=SAIX(I,1)*U(I,1)
      VN(I,1)=ETAX(I,1)*U(I,1)
      RHO(I,1)=(SY*RHOIM1-0.5*EY*(4.*RHO(I,2)-RHO(I,3)))/DENOM
      E0(I,1)=(SY*E0IM1-0.5*EY*(4.*E0(I,2)-E0(I,3)))/DENOM
      E(I,1)=E0(I,1)/RHO(I,1)-0.5*(U(I,1)**2+V(I,1)**2)
      T(I,1)=FT(RHO(I,1),E(I,1))
      AMW(I,1)=FAMW(RHO(I,1),T(I,1))
      P(I,1)=RHO(I,1)*(RG/AMW(I,1))*T(I,1)
      RHOU(I,1)=RHO(I,1)*U(I,1)
      RHOV(I,1)=RHO(I,1)*V(I,1)
      RETURN
*****************************************************************
      ENTRY WALLBC(II)
*****************************************************************
*
*     WALL BOUNDARY CONDITIONS FOR VISCOUS FLOW
*
      I=II
      J=JL
      CC1=ETAX(I,J)*SAIX(I,J)+ETAY(I,J)*SAIY(I,J)
      CC2=ETAX(I,J)**2+ETAY(I,J)**2
      IF(I.NE.IL) THEN
        AM=-0.5*CC1
        BM=1.5*CC2
        CM=0.5*CC1
        DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
      ELSE
        AM=-CC1
        BM=CC1+1.5*CC2
        CM=0.
        DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
      END IF
      IP1=I+1
      IF(I.EQ.IL) IP1=IL
```

```
**********************************************************************
*
*     LAMINAR VISCOSITY CALCULATION
*
      I=II
*
*     USE SUTHELAND LAW
*
      DO 10 J=1,JL
      TOS=TREF+SCONST
      TT=T(I,J)
      TTS=TT+SCONST
      ZMU(J)=ZMU0*TOS/TTS*(TT/TREF)**1.5
*
*     USE CONSTANT VISCOSITY
*
      ZMU(J)=ZMU0
*
*     USE EXPONENTIAL VISCOSITY LAW
*
      ZMU(J)=ZMU0*(TT/TREF)**OMEGA
*
*     USE DATA
*
      ZMU(J)=FZMU(RHO(I,J),E(I,J))
   10 CONTINUE
      RETURN
**********************************************************************
      ENTRY MUTUR(II)
**********************************************************************
*
*     BALDWIN - LOMAX TURBULENCE MODEL
*
      I=II
      FYMAX=0.0
      YMAX=0.0
      UDIF=0.
      YVERT(JL)=0.0
      TAUW=ZMU(JL)*ABS(ETAY(I,JL)*(U(I,JL)-U(I,JL-1))
     >     -ETAX(I,JL)*(V(I,JL)-V(I,JL-1)))
      CYP=SQRT(RHO(I,JL)*TAUW)/ZMU(JL)
*
      DO 20 KK=2,JL1
      K=JL+1-KK
      YVER=YVERT(K+1)+1.0/SQRT(ETAX(I,K)**2+ETAY(I,K)**2)
      OMG=ABS(ETAY(I,K)*(U(I,K+1)-U(I,K-1))*.5
     >    +SAIY(I,K)*(U(I,K)-U(I-1,K))
     >    -ETAX(I,K)*(V(I,K+1)-V(I,K-1))*.5
     >    -SAIX(I,K)*(V(I,K)-V(I-1,K)))
      YPLUS=CYP*YVER
      CEXP=YPLUS/AP
      IF(CEXP.GT.500.) CEXP=500.
      TURLEN=VKCON*YVER*(1.00-EXP(-CEXP))
      ZMUI(K)=RHO(I,K)*OMG*TURLEN**2
      FY=TURLEN/VKCON*OMG
```

```
      UTOTAL=SQRT(U(I,K)**2+V(I,K)**2)
      IF(UTOTAL.GE.UDIF) UDIF=UTOTAL
      IF(FY.LT.FYMAX) GO TO 20
      FYMAX=FY
      YMAX=YVER
   20 YVERT(K)=YVER
*
      VXDIF=UDIF
      FWAKE1=YMAX*FYMAX
      FWAKE2=CWK*YMAX*VXDIF**2/FYMAX
      FWAKE=AMIN1(FWAKE1,FWAKE2)
*
      DO 30 KK=2, JL1
      K=JL+1-KK
      FKLEB=(CKLEB*YVERT(K)/YMAX)**6
      FKLEB=1./(1.0+5.5*FKLEB)
      ZMUO=XK*CCP*RHO(I,K)*FWAKE*FKLEB
      IF(ZMUI(K).GT.ZMUO) THEN
        ZMUTUR=ZMUO
      ELSE
        ZMUTUR=ZMUI(K)
      END IF
      ZMUT(K)=ZMUTUR
      ZMU(K)=ZMU(K)+ZMUTUR
      WRITE (77,500) K,Y(I,K),YVERT(K),U(I,K),ZMUI(K),ZMUO,ZMU(K)
  500 FORMAT(2X,I3,6(2X,D13.6))
   30 CONTINUE
*
      ZMUT(1)=0.
      ZMUT(JL)=0.
      RETURN
*****************************************************************
      ENTRY KLAM(II)
*****************************************************************
      I=II
      DO 40 J=1,JL
      ZK(J)=FZK(RHO(I,J),E(I,J))
   40 CONTINUE
      RETURN
*****************************************************************
      ENTRY KTUR(II)
*****************************************************************
      I=II
      DO 50 J=1,JL
      CPT=RG/AMW(I,J)+E(I,J)/T(I,J)
      ZKT=CPT/PRNT*ZMUT(J)
      ZK(J)=ZK(J)+ZKT
   50 CONTINUE
      RETURN
      END
      SUBROUTINE MCONST
*****************************************************************
*
*     SUBROUTINE FOR CALCULATING METRIC TERMS AT THE MIDPOINT
*     (I,J+1/2), (FOR THE VISCOUS VECTOR DMVS/DETA)
```

```
*
*              4    2     2
*     A1(I,J)=(-ETA  +ETA  )
*              3   X     Y
*
*             1
*     A2(I,J)=-ETA *ETA
*             3   X    Y
*
*                  2 4    2
*     A3(I,J)=(ETA  +-ETA  )
*                 X  3   Y
*
*                  2     2
*     A4(I,J)=(ETA  +ETA  )
*                 X      Y
*
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
     >        PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
      DATA FD3,OD3 /1.333333333333,0.333333333333/
*****************************************************************
      DO 10 I=2,IL
      DO 10 J=1,JL1
      IF(I.EQ.IL) THEN
        XSAI=0.5*(X(I,J)+X(I,J+1)-X(I-1,J)-X(I-1,J+1))
        YSAI=0.5*(Y(I,J)+Y(I,J+1)-Y(I-1,J)-Y(I-1,J+1))
      ELSE
        YSAI=0.25*(Y(I+1,J+1)+Y(I+1,J)-Y(I-1,J+1)-Y(I-1,J))
        XSAI=0.25*(X(I+1,J+1)+X(I+1,J)-X(I-1,J+1)-X(I-1,J))
      END IF
      YETA=Y(I,J+1)-Y(I,J)
      XETA=X(I,J+1)-X(I,J)
      RJJ=1./(XSAI*YETA-XETA*YSAI)
      A1(I,J)=RJJ*RJJ*(FD3*YSAI**2+XSAI**2)
      A2(I,J)=-RJJ*RJJ*OD3*XSAI*YSAI
      A3(I,J)=RJJ*RJJ*(YSAI**2+FD3*XSAI**2)
      A4(I,J)=RJJ*RJJ*(XSAI**2+YSAI**2)
   10 CONTINUE
```

```
      RETURN
      END
      SUBROUTINE AVERAGE(IA,IROE,CXM,CYM,RHOM,UM,VM,EOM,PM,UCNM,
     >                   EM,TM,AMWM,I,J)
*****************************************************************
*
*     SUBROUTINE FOR AVERAGING FLOW PROPERTIES
*
*     IF IA=1, AVERAGING OF Q FOR A MATRIX
*     IF IA=2, AVERAGING OF Q FOR B MATRIX
*     IF IROE=0, MEAN VALUE AVERAGING
*     IF IROE=1, ROE AVERAGING
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >       G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >       U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >       ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >       ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >       DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >       A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >       RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
     >       P0,T0,TWALL,PB,SUM(4)
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
*****************************************************************
      IROE=1
      IF(IA.EQ.1) THEN
        I1=I
        J1=J
        I2=I+1
        J2=J
        CXM=0.5*(SAIX(I1,J1)+SAIX(I2,J2))
        CYM=0.5*(SAIY(I1,J1)+SAIY(I2,J2))
      END IF
      IF(IA.EQ.2) THEN
        I1=I
        J1=J
        I2=I
        J2=J+1
        CXM=0.5*(ETAX(I1,J1)+ETAX(I2,J2))
        CYM=0.5*(ETAY(I1,J1)+ETAY(I2,J2))
      END IF
      IF(IROE.EQ.0) THEN
        RHOM=0.5*(RHO(I1,J1)+RHO(I2,J2))
        UM=0.5*(U(I1,J1)+U(I2,J2))
        VM=0.5*(V(I1,J1)+V(I2,J2))
        EOM=0.5*(E0(I1,J1)+E0(I2,J2))
        PM=0.5*(P(I1,J1)+P(I2,J2))
        IF(IA.EQ.1) UCNM=0.5*(UN(I1,J1)+UN(I2,J2))
        IF(IA.EQ.2) UCNM=0.5*(VN(I1,J1)+VN(I2,J2))
```

```
        UCNM=CXM*UM+CYM*VM
        EM=EOM/RHOM-0.5*(UM**2+VM**2)
        TM=FT(RHOM,EM)
        AMWM=FAMW(RHOM,TM)
      END IF
      IF(IROE.EQ.1) THEN
        SQRHO1=SQRT(RHO(I1,J1))
        SQRHO2=SQRT(RHO(I2,J2))
        DENOM=SQRHO1+SQRHO2
        RHOM=(RHO(I1,J1)*SQRHO1+RHO(I2,J2)*SQRHO2)/DENOM
        UM=(U(I1,J1)*SQRHO1+U(I2,J2)*SQRHO2)/DENOM
        VM=(V(I1,J1)*SQRHO1+V(I2,J2)*SQRHO2)/DENOM
        HT1=(E0(I1,J1)+P(I1,J1))/RHO(I1,J1)
        HT2=(E0(I2,J2)+P(I2,J2))/RHO(I2,J2)
        HTM=(HT1*SQRHO1+HT2*SQRHO2)/DENOM
*     ARITHMETIC AVERAGING OF "REAL GAS GAMMA"
        G1=1.+(RG/AMW(I1,J1))/(E(I1,J1)/T(I1,J1))
        G2=1.+(RG/AMW(I2,J2))/(E(I2,J2)/T(I2,J2))
        GM=0.5*(G1+G2)
        PM=(GM-1.)/GM*(RHOM*HTM-0.5*RHOM*(UM**2+VM**2))
        EOM=RHOM*HTM-PM
        UCNM=CXM*UM+CYM*VM
        EM=EOM/RHOM-0.5*(UM**2+VM**2)
        TM=FT(RHOM,EM)
        AMWM=FAMW(RHOM,TM)
      END IF
      RETURN
      END
      SUBROUTINE JCBCL
*****************************************************************
*
*     SUBROUTINE FOR JACOBIANS CALCULATIONS
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
     >        P0,T0,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
      DIMENSION A(4,4),B(4,4),C(4,4),AA(4,4),BB(4,4),DIAG(4),
     >          D(4,4)
*****************************************************************
      ENTRY JCBAB(IA,IMID,A,I,J)
```

```
**********************************************************************
*
*     JACOBIAN A OR B MATRIX CALCULATIONS
*     A=DE/DQ, B=DF/DQ
*
*     IF IA=1, ACAP MATRIX
*     IF IA=2, BCAP MATRIX
*
**********************************************************************
      IF((IA.EQ.1.AND.IMID.EQ.0).OR.
     >   (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN
        CX=SAIX(I,J)
        CY=SAIY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
        QEO=EO(I,J)
        QP=P(I,J)
        QCN=UN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF((IA.EQ.2.AND.IMID.EQ.0).OR.
     >   (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN
        CX=ETAX(I,J)
        CY=ETAY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
        QEO=EO(I,J)
        QP=P(I,J)
        QCN=VN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF(IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      IF(IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      AR=FAR(QP,QRHO,QT,QE,QAMW)
      AE=FAE(QP,QRHO,QT,QE,QAMW)
      AER=AE/QRHO
      DPDR=AR+AER*(-QEO/QRHO+(QU**2+QV**2))
      DPDU=-AER*QU
      DPDV=-AER*QV
      DPDE=AER
      A(1,1)=0.0
      A(1,2)=CX
      A(1,3)=CY
```

```
      A(1,4)=0.0
      A(2,1)=-QU*QCN+CX*DPDR
      A(2,2)=QCN+CX*(QU+DPDU)
      A(2,3)=CY*QU+CX*DPDV
      A(2,4)=CX*DPDE
      A(3,1)=-QV*QCN+CY*DPDR
      A(3,2)=CX*QV+CY*DPDU
      A(3,3)=QCN+CY*(QV+DPDV)
      A(3,4)=CY*DPDE
      A(4,1)=QCN*(DPDR-(QE0+QP)/QRHO)
      A(4,2)=QCN*DPDU+CX*(QE0+QP)/QRHO
      A(4,3)=QCN*DPDV+CY*(QE0+QP)/QRHO
      A(4,4)=QCN*(1.+DPDE)
      RETURN
*****************************************************************
      ENTRY JCBABPM(IA,IB,IMID,A,I,J)
*****************************************************************
*
*     SPLITTED JACOBIAN A-PLUS, A-MINUS, B-PLUS, OR B-MINUS
*      +  -1  -1          +          -  -1  -1          -
*     A =T  *P  *(LAMBDA) *P*T,  A =T  *P  *(LAMBDA) *P*T
*
*      +  -1  -1          +          -  -1  -1          -
*     B =T  *P  *(LAMBDA) *P*T,  B =T  *P  *(LAMBDA) *P*T
*
*     IF IA=1 IB=1 - A-PLUS MATRIX
*     IF IA=1 IB=2 - A-MINUS MATRIX
*     IF IA=2 IB=1 - B-PLUS MATRIX
*     IF IA=2 IB=2 - B-MINUS MATRIX
*     IF IMID=0 - JACOBIAN CALCULATED IN POINT (I,J)
*     IF IMID=1 IA=1 - JACOBIAN CALCULATED IN POINT (I+1/2,J)
*     IF IMID=1 IA=2 - JACOBIAN CALCULATED IN POINT (I,J+1/2)
*
*****************************************************************
      IF((IA.EQ.1.AND.IMID.EQ.0).OR.
     >   (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN
        CX=SAIX(I,J)
        CY=SAIY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
        QE0=E0(I,J)
        QP=P(I,J)
        QCN=UN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF((IA.EQ.2.AND.IMID.EQ.0).OR.
     >   (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN
        CX=ETAX(I,J)
        CY=ETAY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
```

```
        QEO=EO(I,J)
        QP=P(I,J)
        QCN=VN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF(IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      IF(IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      CO=SQRT(FCO2(QP,QRHO,QT,QE,QAMW))
      CQ=SQRT(CX**2+CY**2)
      CQCO=CQ*CO
      EIG4=QCN-CQCO
      IF(IB.EQ.1) THEN
        DIAG(1)=QCN
        DIAG(2)=QCN
        DIAG(3)=QCN+CQCO
        DIAG(4)=0.
        IF(EIG4.GE.0.0) DIAG(4)=EIG4
      END IF
      IF(IB.EQ.2) THEN
        DIAG(1)=0.
        DIAG(2)=0.
        DIAG(3)=0.
        DIAG(4)=0.
        IF(EIG4.LT.0.0) DIAG(4)=EIG4
      END IF
      CALL TMPM(IA,IMID,AA,I,J)
      DO 30 II=1,4
      DO 30 JJ=1,4
      BB(II,JJ)=DIAG(II)*AA(II,JJ)
   30 CONTINUE
      CALL PPTP(IA,IMID,AA,I,J)
      CALL MMM(4,AA,BB,A)
      RETURN
*****************************************************************
      ENTRY JCBD(D,I,J)
*****************************************************************
*
*     SOURCE TERM JACOBIAN MATRIX, D=DH'/DQ
*
*     H(1)=0.
*     H(2)=0.
*     H(3)=(P-4./3.*MU*V/Y)/J
*     H(4)=0.
*
*****************************************************************
      CALL SZERO(4,D)
      IF(IVISC.EQ.0) THEN
```

```
        ZMU(J)=0.
        DMUDR=0.
        DMUDU=0.
        DMUDV=0.
        DMUDE=0.
      ELSE
        CR=FDMUDRE(RHO(I,J),E(I,J))
        CE=FDMUDER(RHO(I,J),E(I,J))
        CER=CE/RHO(I,J)
        DMUDR=CR+CER*(-EO(I,J)/RHO(I,J)+(U(I,J)**2+V(I,J)**2))
        DMUDU=-CER*U(I,J)
        DMUDV=-CER*V(I,J)
        DMUDE=CER
      END IF
      AR=FAR(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))
      AE=FAE(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))
      AER=AE/RHO(I,J)
      DPDR=AR+AER*(-EO(I,J)/RHO(I,J)+(U(I,J)**2+V(I,J)**2))
      DPDU=-AER*U(I,J)
      DPDV=-AER*V(I,J)
      DPDE=AER
      RY=4./3./Y(I,J)**2
      D(3,1)=DPDR/Y(I,J)
     >       +IVISC*(-V(I,J)*DMUDR+ZMU(J)*V(I,J)/RHO(I,J))*RY
      D(3,2)=DPDU/Y(I,J)
     >       +IVISC*(-V(I,J)*DMUDU)*RY
      D(3,3)=DPDV/Y(I,J)
     >       +IVISC*(-V(I,J)*DMUDV-ZMU(J)/RHO(I,J))*RY
      D(3,4)=DPDE/Y(I,J)
     >       +IVISC*(-V(I,J)*DMUDE)*RY
      RETURN
*****************************************************************
      ENTRY JCBMVS(A,B,C,I,J)
*****************************************************************
*
*     VISCOUS JACOBIAN MATRIX, MVS=-D(DSVS'/DETA+H'')/DQ
*
*     H(1)=0.
*
*          1   2
*     H(2)=-*(--*ETA *D(MU*V)/DETA)
*          J   3    X
*
*          1  2                   2
*     H(3)=-*(-*ETA *MU*DU/DETA--*ETA *V*D(MU)/DETA)
*          J  3    X              3    Y
*
*          1   2                  2
*     H(4)=-*(--*ETA *D(MU*U*V)/DETA--*ETA *D(MU*V*V)/DETA)
*          J   3    X             3    Y
*
*****************************************************************
      JP1=J+1
      JM1=J-1
      YJP1   = Y(I,JP1)/RJ(I,JP1)
```

```
      YJP    = 0.5*(Y(I,J)/RJ(I,J)+Y(I,JP1)/RJ(I,JP1))
      YJ     = Y(I,J)/RJ(I,J)
      YJM    = 0.5*(Y(I,J)/RJ(I,J)+Y(I,JM1)/RJ(I,JM1))
      YJM1   = Y(I,JM1)/RJ(I,JM1)
      EXJ    = 1./3.*ETAX(I,J)/RJ(I,J)
      EYJ    = 1./3.*ETAY(I,J)/RJ(I,J)
      RHOP   = 0.5*(RHO(I,J)+RHO(I,JP1))
      RHOM   = 0.5*(RHO(I,J)+RHO(I,JM1))
      UP     = 0.5*(U(I,J)+U(I,JP1))
      UM     = 0.5*(U(I,J)+U(I,JM1))
      VP     = 0.5*(V(I,J)+V(I,JP1))
      VM     = 0.5*(V(I,J)+V(I,JM1))
      EP     = 0.5*(E(I,J)+E(I,JP1))
      EM     = 0.5*(E(I,J)+E(I,JM1))
      ORP1   = 1./RHO(I,JP1)
      OR     = 1./RHO(I,J)
      ORM1   = 1./RHO(I,JM1)
      UORP1  = U(I,JP1)/RHO(I,JP1)
      UOR    = U(I,J)/RHO(I,J)
      UORM1  = U(I,JM1)/RHO(I,JM1)
      VORP1  = V(I,JP1)/RHO(I,JP1)
      VOR    = V(I,J)/RHO(I,J)
      VORM1  = V(I,JM1)/RHO(I,JM1)
      U2P1   = U(I,JP1)**2
      U2P    = (0.5*(U(I,J)+U(I,JP1)))**2
      U2     = U(I,J)**2
      U2M    = (0.5*(U(I,J)+U(I,JM1)))**2
      U2M1   = U(I,JM1)**2
      V2P1   = V(I,JP1)**2
      V2P    = (0.5*(V(I,J)+V(I,JP1)))**2
      V2     = V(I,J)**2
      V2M    = (0.5*(V(I,J)+V(I,JM1)))**2
      V2M1   = V(I,JM1)**2
      UVP1   = U(I,JP1)*V(I,JP1)
      UV     = U(I,J)*V(I,J)
      UVM1   = U(I,JM1)*V(I,JM1)
      U2ORP1 = U2P1*ORP1
      U2OR   = U2*OR
      U2ORM1 = U2M1*ORM1
      V2ORP1 = V2P1*ORP1
      V2OR   = V2*OR
      V2ORM1 = V2M1*ORM1
      UVORP1 = UVP1*ORP1
      UVOR   = UV*OR
      UVORM1 = UVM1*ORM1
      ZMUP   = 0.5*(ZMU(J)+ZMU(JP1))
      ZMUM   = 0.5*(ZMU(J)+ZMU(JM1))
      YJZMUP = YJP*ZMUP
      YJZMUM = YJM*ZMUM
      ZKP    = 0.5*(ZK(J)+ZK(JP1))
      ZKM    = 0.5*(ZK(J)+ZK(JM1))
      YJZKP  = YJP*ZKP
      YJZKM  = YJM*ZKM
      EOORP1 = EO(I,JP1)/RHO(I,JP1)
      EOORP  = 0.5*(EO(I,J)/RHO(I,J)+EO(I,JP1)/RHO(I,JP1))
```

```
      EOOR   = EO(I,J)/RHO(I,J)
      EOORM  = 0.5*(EO(I,J)/RHO(I,J)+EO(I,JM1)/RHO(1,JM1))
      EOORM1 = EO(I,JM1)/RHO(I,JM1)
*
      BR=FDTDRE(RHO(I,JP1),E(I,JP1))
      BE=FDTDER(RHO(I,JP1),E(I,JP1))
      BER=BE/RHO(I,JP1)
      DTDRP1=BR+BER*(-EOORP1+(U2P1+V2P1))
      DTDUP1=-BER*U(I,JP1)
      DTDVP1=-BER*V(I,JP1)
      DTDEP1=BER
      BR=FDTDRE(RHO(I,J),E(I,J))
      BE=FDTDER(RHO(I,J),E(I,J))
      BER=BE/RHO(I,J)
      DTDR=BR+BER*(-EOOR+(U2+V2))
      DTDU=-BER*U(I,J)
      DTDV=-BER*V(I,J)
      DTDE=BER
      BR=FDTDRE(RHO(I,JM1),E(I,JM1))
      BE=FDTDER(RHO(I,JM1),E(I,JM1))
      BER=BE/RHO(I,JM1)
      DTDRM1=BR+BER*(-EOORM1+(U2M1+V2M1))
      DTDUM1=-BER*U(I,JM1)
      DTDVM1=-BER*V(I,JM1)
      DTDEM1=BER
*
      CR=FDMUDRE(RHO(I,JP1),E(I,JP1))
      CE=FDMUDER(RHO(I,JP1),E(I,JP1))
      CER=CE/RHO(I,JP1)
      DMUDRP1=CR+CER*(-EOORP1+(U2P1+V2P1))
      DMUDUP1=-CER*U(I,JP1)
      DMUDVP1=-CER*V(I,JP1)
      DMUDEP1=CER
      CR=FDMUDRE(RHOP,EP)
      CE=FDMUDER(RHOP,EP)
      CER=CE/RHOP
      DMUDRP=CR+CER*(-EOORP+(U2P+V2P))
      DMUDUP=-CER*UP
      DMUDVP=-CER*VP
      DMUDEP=CER
      CR=FDMUDRE(RHO(I,J),E(I,J))
      CE=FDMUDER(RHO(I,J),E(I,J))
      CER=CE/RHO(I,J)
      DMUDR=CR+CER*(-EOOR+(U2+V2))
      DMUDU=-CER*U(I,J)
      DMUDV=-CER*V(I,J)
      DMUDE=CER
      CR=FDMUDRE(RHOM,EM)
      CE=FDMUDER(RHOM,EM)
      CER=CE/RHOM
      DMUDRM=CR+CER*(-EOORM+(U2M+V2M))
      DMUDUM=-CER*UM
      DMUDVM=-CER*VM
      DMUDEM=CER
      CR=FDMUDRE(RHO(I,JM1),E(I,JM1))
```

```
      CE=FDMUDER(RHO(I,JM1),E(I,JM1))
      CER=CE/RHO(I,JM1)
      DMUDRM1=CR+CER*(-EOORM1+(U2M1+V2M1))
      DMUDUM1=-CER*U(I,JM1)
      DMUDVM1=-CER*V(I,JM1)
      DMUDEM1=CER
*
      DR=FDKDRE(RHOP,EP)
      DE=FDKDER(RHOP,EP)
      DER=DE/RHOP
      DKDRP=DR+DER*(-EOORP+(U2P+V2P))
      DKDUP=-DER*UP
      DKDVP=-DER*VP
      DKDEP=DER
      DR=FDKDRE(RHOM,EM)
      DE=FDKDER(RHOM,EM)
      DER=DE/RHOM
      DKDRM=DR+DER*(-EOORM+(U2M+V2M))
      DKDUM=-DER*UM
      DKDVM=-DER*VM
      DKDEM=DER
*
*     COMPUTE -M=-(DSVS'/DQ)/DETA
*
      IF(JM1.EQ.1) THEN
        CALL SZERO(4,A)
      ELSE
        A(1,1)=0.
        A(1,2)=0.
        A(1,3)=0.
        A(1,4)=0.
        A(2,1)=-DMUDRM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
     >          +YJZMUM*(A1(I,JM1)*UORM1+A2(I,JM1)*VORM1)/YJM1
        A(2,2)=-DMUDUM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
     >          -YJZMUM*A1(I,JM1)*ORM1/YJM1
        A(2,3)=-DMUDVM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
     >          -YJZMUM*A2(I,JM1)*ORM1/YJM1
        A(2,4)=-DMUDEM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
        A(3,1)=-DMUDRM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
     >          +YJZMUM*(A3(I,JM1)*VORM1+A2(I,JM1)*UORM1)/YJM1
        A(3,2)=-DMUDUM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
     >          -YJZMUM*A2(I,JM1)*ORM1/YJM1
        A(3,3)=-DMUDVM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
     >          -YJZMUM*A3(I,JM1)*ORM1/YJM1
        A(3,4)=-DMUDEM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
        A(4,1)=-DMUDRM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1
     >                 +0.5*A3(I,JM1)*V2M1)
     >          +YJZMUM*(A1(I,JM1)*U2ORM1+2.0*A2(I,JM1)*UVORM1
     >                 +A3(I,JM1)*V2ORM1)/YJM1
     >          -DKDRM*A4(I,JM1)*T(I,JM1)
     >          -YJZKM*A4(I,JM1)*DTDRM1/YJM1
        A(4,2)=-DMUDUM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1
     >                 +0.5*A3(I,JM1)*V2M1)
     >          -YJZMUM*(A1(I,JM1)*UORM1+A2(I,JM1)*VORM1)/YJM1
     >          -DKDUM*A4(I,JM1)*T(I,JM1)
```

```
     >          -YJZKM*A4(I,JM1)*DTDUM1/YJM1
        A(4,3)=-DMUDVM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1
     .                 +0.5*A3(I,JM1)*V2M1)
     >          -YJZMUM*(A2(I,JM1)*UORM1+A3(I,JM1)*VORM1)/YJM1
     >          -DKDVM*A4(I,JM1)*T(I,JM1)
     >          -YJZKM*A4(I,JM1)*DTDVM1/YJM1
        A(4,4)=-DMUDEM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1
     >                 +0.5*A3(I,JM1)*V2M1)
     >          -DKDEM*A4(I,JM1)*T(I,JM1)
     >          -YJZKM*A4(I,JM1)*DTDEM1/YJM1
      END IF
      C(1,1)=0.
      C(1,2)=0.
      C(1,3)=0.
      C(1,4)=0.
      C(2,1)=-DMUDRP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
     >        +YJZMUP*(A1(I,J)*UORP1+A2(I,J)*VORP1)/YJP1
      C(2,2)=-DMUDUP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
     >        -YJZMUP*A1(I,J)*ORP1/YJP1
      C(2,3)=-DMUDVP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
     >        -YJZMUP*A2(I,J)*ORP1/YJP1
      C(2,4)=-DMUDEP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
      C(3,1)=-DMUDRP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
     >        +YJZMUP*(A3(I,J)*VORP1+A2(I,J)*UORP1)/YJP1
      C(3,2)=-DMUDUP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
     >        -YJZMUP*A2(I,J)*ORP1/YJP1
      C(3,3)=-DMUDVP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
     >        -YJZMUP*A3(I,J)*ORP1/YJP1
      C(3,4)=-DMUDEP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
      C(4,1)=-DMUDRP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
     >               +0.5*A3(I,J)*V2P1)
     >        +YJZMUP*(A1(I,J)*U2ORP1+2.0*A2(I,J)*UVORP1
     >               +A3(I,J)*V2ORP1)/YJP1
     >        -DKDRP*A4(I,J)*T(I,JP1)
     >        -YJZKP*A4(I,J)*DTDRP1/YJP1
      C(4,2)=-DMUDUP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
     >               +0.5*A3(I,J)*V2P1)
     >        -YJZMUP*(A1(I,J)*UORP1+A2(I,J)*VORP1)/YJP1
     >        -DKDUP*A4(I,J)*T(I,JP1)
     .        -YJZKP*A4(I,J)*DTDUP1/YJP1
      C(4,3)=-DMUDVP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
     >               +0.5*A3(I,J)*V2P1)
     .        -YJZMUP*(A2(I,J)*UORP1+A3(I,J)*VORP1)/YJP1
     >        -DKDVP*A4(I,J)*T(I,JP1)
     >        -YJZKP*A4(I,J)*DTDVP1/YJP1
      C(4,4)=-DMUDEP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
     .               +0.5*A3(I,J)*V2P1)
     >        -DKDEP*A4(I,J)*T(I,JP1)
     >        -YJZKP*A4(I,J)*DTDEP1/YJP1
      B(1,1)=0.
      B(1,2)=0.
      B(1,3)=0.
      B(1,4)=0.
      B(2,1)=(DMUDRP*A1(I,J)+DMUDRM*A1(I,JM1))*U(I,J)
     >      +(DMUDRP*A2(I,J)+DMUDRM*A2(I,JM1))*V(I,J)
```

```
     >       -(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*UOR/YJ
     >       -(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*VOR/YJ
      B(2,2)=(DMUDUP*A1(I,J)+DMUDUM*A1(I,JM1))*U(I,J)
     >       +(DMUDUP*A2(I,J)+DMUDUM*A2(I,JM1))*V(I,J)
     >       +(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*OR/YJ
      B(2,3)=(DMUDVP*A1(I,J)+DMUDVM*A1(I,JM1))*U(I,J)
     >       +(DMUDVP*A2(I,J)+DMUDVM*A2(I,JM1))*V(I,J)
     >       +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*OR/YJ
      B(2,4)=(DMUDEP*A1(I,J)+DMUDEM*A1(I,JM1))*U(I,J)
     >       +(DMUDEP*A2(I,J)+DMUDEM*A2(I,JM1))*V(I,J)
      B(3,1)=(DMUDRP*A3(I,J)+DMUDRM*A3(I,JM1))*V(I,J)
     >       +(DMUDRP*A2(I,J)+DMUDRM*A2(I,JM1))*U(I,J)
     >       -(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*VOR/YJ
     >       -(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*UOR/YJ
      B(3,2)=(DMUDUP*A3(I,J)+DMUDUM*A3(I,JM1))*V(I,J)
     >       +(DMUDUP*A2(I,J)+DMUDUM*A2(I,JM1))*U(I,J)
     >       +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*OR/YJ
      B(3,3)=(DMUDVP*A3(I,J)+DMUDVM*A3(I,JM1))*V(I,J)
     >       +(DMUDVP*A2(I,J)+DMUDVM*A2(I,JM1))*U(I,J)
     >       +(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*OR/YJ
      B(3,4)=(DMUDEP*A3(I,J)+DMUDEM*A3(I,JM1))*V(I,J)
     >       +(DMUDEP*A2(I,J)+DMUDEM*A2(I,JM1))*U(I,J)
      B(4,1)=0.5*(DMUDRP*A1(I,J)+DMUDRM*A1(I,JM1))*U2
     >       +(DMUDRP*A2(I,J)+DMUDRM*A2(I,JM1))*UV
     >       +0.5*(DMUDRP*A3(I,J)+DMUDRM*A3(I,JM1))*V2
     >       -(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*U2OR/YJ
     >       -2.0*(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*UVOR/YJ
     >       -(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*V2OR/YJ
     >       +(DKDRP*A4(I,J)+DKDRM*A4(I,JM1))*T(I,J)
     >       +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDR/YJ
      B(4,2)=0.5*(DMUDUP*A1(I,J)+DMUDUM*A1(I,JM1))*U2
     >       +(DMUDUP*A2(I,J)+DMUDUM*A2(I,JM1))*UV
     >       +0.5*(DMUDUP*A3(I,J)+DMUDUM*A3(I,JM1))*V2
     >       +(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*UOR/YJ
     >       +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*VOR/YJ
     >       +(DKDUP*A4(I,J)+DKDUM*A4(I,JM1))*T(I,J)
     >       +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDU/YJ
      B(4,3)=0.5*(DMUDVP*A1(I,J)+DMUDVM*A1(I,JM1))*U2
     >       +(DMUDVP*A2(I,J)+DMUDVM*A2(I,JM1))*UV
     >       +0.5*(DMUDVP*A3(I,J)+DMUDVM*A3(I,JM1))*V2
     >       +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*UOR/YJ
     >       +(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*VOR/YJ
     >       +(DKDVP*A4(I,J)+DKDVM*A4(I,JM1))*T(I,J)
     >       +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDV/YJ
      B(4,4)=0.5*(DMUDEP*A1(I,J)+DMUDEM*A1(I,JM1))*U2
     >       +(DMUDEP*A2(I,J)+DMUDEM*A2(I,JM1))*UV
     >       +0.5*(DMUDEP*A3(I,J)+DMUDEM*A3(I,JM1))*V2
     >       +(DKDEP*A4(I,J)+DKDEM*A4(I,JM1))*T(I,J)
     >       +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDE/YJ
*
*     COMPUTE -D''-DH''/DQ
*     AND ADD TO PREVIOUS RESULTS
*
      IF(JM1.EQ.1) THEN
        CALL SZERO(4,A)
```

```
      ELSE
        A(2,1)=A(2,1)-EXJ*(V(I,JM1)*DMUDRM1-ZMU(JM1)*VORM1)/YJM1
        A(2,2)=A(2,2)-EXJ*V(I,JM1)*DMUDUM1/YJM1
        A(2,3)=A(2,3)-EXJ*(V(I,JM1)*DMUDVM1+ZMU(JM1)*ORM1)/YJM1
        A(2,4)=A(2,4)-EXJ*V(I,JM1)*DMUDEM1/YJM1
        A(3,1)=A(3,1)+EXJ*DMUDR/YJ*U(I,JM1)
     >                -EXJ*ZMU(J)*UORM1/YJM1
     >                +EYJ*VOR/YJ*ZMU(JM1)
     >                -EYJ*V(I,J)*DMUDRM1/YJM1
        A(3,2)=A(3,2)+EXJ*DMUDU/YJ*U(I,JM1)
     >                +EXJ*ZMU(J)*ORM1/YJM1
     >                -EYJ*V(I,J)*DMUDUM1/YJM1
        A(3,3)=A(3,3)+EXJ*DMUDV/YJ*U(I,JM1)
     >                -EYJ*OR/YJ*ZMU(JM1)
     >                -EYJ*V(I,J)*DMUDVM1/YJM1
        A(3,4)=A(3,4)+EXJ*DMUDE/YJ*U(I,JM1)
     >                -EYJ*V(I,J)*DMUDEM1/YJM1
        A(4,1)=A(4,1)-EXJ*(DMUDRM1-2.0*ZMU(JM1)*ORM1)*UVM1/YJM1
     >                -EYJ*(DMUDRM1-2.0*ZMU(JM1)*ORM1)*V2M1/YJM1
        A(4,2)=A(4,2)-EXJ*(DMUDUM1*UVM1+ZMU(JM1)*VORM1)/YJM1
     >                -EYJ*(DMUDUM1*V2M1)/YJM1
        A(4,3)=A(4,3)-EXJ*(DMUDVM1*UVM1+ZMU(JM1)*UORM1)/YJM1
     >                -EYJ*(DMUDVM1*V2M1+2.0*ZMU(JM1)*VORM1)/YJM1
        A(4,4)=A(4,4)-EXJ*DMUDEM1*UVM1/YJM1
     >                -EYJ*DMUDEM1*V2M1/YJM1
      END IF
      C(2,1)=C(2,1)+EXJ*(V(I,JP1)*DMUDRP1-ZMU(JP1)*VORP1)/YJP1
      C(2,2)=C(2,2)+EXJ*V(I,JP1)*DMUDUP1/YJP1
      C(2,3)=C(2,3)+EXJ*(V(I,JP1)*DMUDVP1+ZMU(JP1)*ORP1)/YJP1
      C(2,4)=C(2,4)+EXJ*V(I,JP1)*DMUDEP1/YJP1
      C(3,1)=C(3,1)-EXJ*DMUDR/YJ*U(I,JP1)
     >              +EXJ*ZMU(J)*UORP1/YJP1
     >              -EYJ*VOR/YJ*ZMU(JP1)
     >              +EYJ*V(I,J)*DMUDRP1/YJP1
      C(3,2)=C(3,2)-EXJ*DMUDU/YJ*U(I,JP1)
     >              -EXJ*ZMU(J)*ORP1/YJP1
     >              +EYJ*V(I,J)*DMUDUP1/YJP1
      C(3,3)=C(3,3)-EXJ*DMUDV/YJ*U(I,JP1)
     >              +EYJ*OR/YJ*ZMU(JP1)
     >              +EYJ*V(I,J)*DMUDVP1/YJP1
      C(3,4)=C(3,4)-EXJ*DMUDE/YJ*U(I,JP1)
     >              +EYJ*V(I,J)*DMUDEP1/YJP1
      C(4,1)=C(4,1)+EXJ*(DMUDRP1-2.0*ZMU(JP1)*ORP1)*UVP1/YJP1
     >              +EYJ*(DMUDRP1-2.0*ZMU(JP1)*ORP1)*V2P1/YJP1
      C(4,2)=C(4,2)+EXJ*(DMUDUP1*UVP1+ZMU(JP1)*VORP1)/YJP1
     >              +EYJ*DMUDUP1*V2P1/YJP1
      C(4,3)=C(4,3)+EXJ*(DMUDVP1*UVP1+ZMU(JP1)*UORP1)/YJP1
     >              +EYJ*(DMUDVP1*V2P1+2.0*ZMU(JP1)*VORP1)/YJP1
      C(4,4)=C(4,4)+EXJ*DMUDEP1*UVP1/YJP1
     >              +EYJ*DMUDEP1*V2P1/YJP1
      RETURN
      END
      SUBROUTINE EIGMTX
*****************************************************************
*
```

```
*     SUBROUTINE FOR EIGENVECTOR MATRIX CALCULATION
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
     >        PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
      DIMENSION A(4,4)
*****************************************************************
      ENTRY TMPM(IA,IMID,A,I,J)
*****************************************************************
*
*                      -1  -1
*     CALCULATION OF T  *P   MATRIX
*
*     IF IA=1 IMID=0 - XI MATRIX CALCULATED IN POINT (I,J)
*     IF IA=2 IMID=0 - ETA MATRIX CALCULATED IN POINT (I,J)
*     IF IA=1 IMID=1 - XI MATRIX CALCULATED IN POINT (I+1/2,J)
*     IF IA=2 IMID=1 - ETA MATRIX CALCULATED IN POINT (I,J+1/2)
*
*****************************************************************
      IF((IA.EQ.1.AND.IMID.EQ.0).OR.
     >   (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN
        CX=SAIX(I,J)
        CY=SAIY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
        QEO=EO(I,J)
        QP=P(I,J)
        QCN=UN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF((IA.EQ.2.AND.IMID.EQ.0).OR.
     >   (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN
        CX=ETAX(I,J)
        CY=ETAY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
```

```
        QE0=E0(I,J)
        QP=P(I,J)
        QCN=VN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF(IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QE0,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      IF(IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QE0,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      SQ2=SQRT(2.0)
      C=SQRT(FC02(QP,QRHO,QT,QE,QAMW))
      AR=FAR(QP,QRHO,QT,QE,QAMW)
      AE=FAE(QP,QRHO,QT,QE,QAMW)
      AER=AE/QRHO
      DPDR=AR+AER*(-QE0/QRHO+(QU**2+QV**2))
      DPDU=-AER*QU
      DPDV=-AER*QV
      DPDE=AER
      C1=CX/SQRT(CX**2+CY**2)
      C2=CY/SQRT(CX**2+CY**2)
      A(1,1)=1.-DPDR/C**2
      A(1,2)=-DPDU/C**2
      A(1,3)=-DPDV/C**2
      A(1,4)=-DPDE/C**2
      A(2,1)=-(C2*QU-C1*QV)/QRHO
      A(2,2)=C2/QRHO
      A(2,3)=-C1/QRHO
      A(2,4)=0.
      A(3,1)=(-(C1*QU+C2*QV)+DPDR/C)/SQ2/QRHO
      A(3,2)=(C1+DPDU/C)/SQ2/QRHO
      A(3,3)=(C2+DPDV/C)/SQ2/QRHO
      A(3,4)=DPDE/C/SQ2/QRHO
      A(4,1)=((C1*QU+C2*QV)+DPDR/C)/SQ2/QRHO
      A(4,2)=(-C1+DPDU/C)/SQ2/QRHO
      A(4,3)=(-C2+DPDV/C)/SQ2/QRHO
      A(4,4)=DPDE/C/SQ2/QRHO
      RETURN
*****************************************************************
      ENTRY PPTP(IA,IMID,A,I,J)
*****************************************************************
*
*     CALCULATION OF P*T MATRIX
*
*     IF IA=1 IMID=0 - XI MATRIX CALCULATED IN POINT (I,J)
*     IF IA=2 IMID=0 - ETA MATRIX CALCULATED IN POINT (I,J)
*     IF IA=1 IMID=1 - XI MATRIX CALCULATED IN POINT (I+1/2,J)
*     IF IA=2 IMID=1 - ETA MATRIX CALCULATED IN POINT (I,J+1/2)
*
*****************************************************************
```

```
      IF((IA.EQ.1.AND.IMID.EQ.0).OR.
     >   (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN
        CX=SAIX(I,J)
        CY=SAIY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
        QEO=EO(I,J)
        QP=P(I,J)
        QCN=UN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF((IA.EQ.2.AND.IMID.EQ.0).OR.
     >   (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN
        CX=ETAX(I,J)
        CY=ETAY(I,J)
        QRHO=RHO(I,J)
        QU=U(I,J)
        QV=V(I,J)
        QEO=EO(I,J)
        QP=P(I,J)
        QCN=VN(I,J)
        QE=E(I,J)
        QT=T(I,J)
        QAMW=AMW(I,J)
      END IF
      IF(IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      IF(IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
        CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
     >               QE,QT,QAMW,I,J)
      END IF
      SQ2=1./SQRT(2.0)
      C=SQRT(FCO2(QP,QRHO,QT,QE,QAMW))
      AR=FAR(QP,QRHO,QT,QE,QAMW)
      AE=FAE(QP,QRHO,QT,QE,QAMW)
      AER=AE/QRHO
      DPDR=AR+AER*(-QEO/QRHO+(QU**2+QV**2))
      DPDU=-AER*QU
      DPDV=-AER*QV
      DPDE=AER
      CXCY=1./SQRT(CX**2+CY**2)
      C1=CX*CXCY
      C2=CY*CXCY
      A(1,1)=1.
      A(1,2)=0.
      A(1,3)=QRHO*SQ2/C
      A(1,4)=A(1,3)
      A(2,1)=QU
      A(2,2)=QRHO*C2
      A(2,3)=SQ2*QRHO*(QU/C+C1)
```

```
      A(2,4)=SQ2*QRHO*(QU/C-C1)
      A(3,1)=QV
      A(3,2)=-QRHO*C1
      A(3,3)=SQ2*QRHO*(QV/C+C2)
      A(3,4)=SQ2*QRHO*(QV/C-C2)
      A(4,1)=QE0/QRHO-QRHO*AR/AE
      A(4,2)=QRHO*(QU*C2-QV*C1)
      TEMP1=SQ2*QRHO**2*C/AE
      TEMP2=SQ2*QRHO*(QU*C1+QV*C2)
      A(4,3)=A(4,1)*QRHO*SQ2/C+TEMP1+TEMP2
      A(4,4)=A(4,1)*QRHO*SQ2/C+TEMP1-TEMP2
      RETURN
      END
      SUBROUTINE FLXCL
*****************************************************************
*
*     SUBROUTINE FOR FLUX VECTOR CALCULATION
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
     >        P0,T0,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
      DIMENSION A(4,4)
*****************************************************************
      ENTRY FLXE(II)
*****************************************************************
*
*     COMPUTE CONVECTIVE FLUX VECTOR E
*
*****************************************************************
      I=II
      DO 10 J=1,JL
      F(I,J,1)=RHO(I,J)*UN(I,J)/RJ(I,J)*Y(I,J)
      F(I,J,2)=(RHOU(I,J)*UN(I,J)+SAIX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      F(I,J,3)=(RHOV(I,J)*UN(I,J)+SAIY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      F(I,J,4)=(E0(I,J)+P(I,J))*UN(I,J)/RJ(I,J)*Y(I,J)
   10 CONTINUE
      RETURN
*****************************************************************
      ENTRY FLXF(II)
*****************************************************************
```

```
*
*     COMPUTE CONVECTIVE FLUX VECTOR F
*
*****************************************************************
      I=II
      DO 20 J=1,JL
      G(I,J,1)=RHO(I,J)*VN(I,J)/RJ(I,J)*Y(I,J)
      G(I,J,2)=(RHOU(I,J)*VN(I,J)+ETAX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      G(I,J,3)=(RHOV(I,J)*VN(I,J)+ETAY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      G(I,J,4)=(EO(I,J)+P(I,J))*VN(I,J)/RJ(I,J)*Y(I,J)
   20 CONTINUE
      RETURN
*****************************************************************
      ENTRY FLXEP(II,IMID)
*****************************************************************
*
*      +
*     E  FLUX VECTOR (IMID=0)
*
*       +  +
*     DE =A (I+1/2,J)*(Q(I+1,J)-Q(I,J)) (IMID=1)
*
*****************************************************************
      I=II
      IF(IMID.EQ.0) THEN
        DO 30 J=1,JL
        CALL JCBABPM(1,1,0,A,I,J)
        DO 31 K=1,4
        F(I,J,K)=0.
        DO 31 JJ=1,4
        F(I,J,K)=F(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
   31   CONTINUE
   30   CONTINUE
      END IF
      IF(IMID.EQ.1.AND.I.NE.IL) THEN
        DO 35 J=1,JL
        CALL JCBABPM(1,1,1,A,I,J)
        DO 36 K=1,4
        F(I,J,K)=0.
        DO 36 JJ=1,4
        YM=0.5*(Y(I,J)+Y(I+1,J))
        RJM=0.5*(RJ(I,J)+RJ(I+1,J))
        F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))/RJM*YM
   36   CONTINUE
   35   CONTINUE
      END IF
      IF(IMID.EQ.1.AND.I.EQ.IL) THEN
        DO 37 J=1,JL
        CALL JCBABPM(1,1,0,A,I,J)
        DO 38 K=1,4
        F(I,J,K)=0.
        DO 38 JJ=1,4
        YM=Y(I,J)
        RJM=RJ(I,J)
        F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I-1,J,JJ))/RJM*YM
```

```
   38    CONTINUE
   37    CONTINUE
      END IF
      RETURN
*****************************************************************
      ENTRY FLXEM(II,IMID)
*****************************************************************
*
*      -
*     E  FLUX VECTOR (IMID=0)
*
*       -  -
*     DE =A (I+1/2,J)*(Q(I+1,J)-Q(I,J)) (IMID=1)
*
*****************************************************************
      I=II
      IF(IMID.EQ.0) THEN
        DO 40 J=1,JL
        CALL JCBABPM(1,2,0,A,I,J)
        DO 41 K=1,4
        G(I,J,K)=0.
        DO 41 JJ=1,4
        G(I,J,K)=G(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
   41   CONTINUE
   40   CONTINUE
      END IF
      IF(IMID.EQ.1.AND.I.NE.IL) THEN
        DO 45 J=1,JL
        CALL JCBABPM(1,2,1,A,I,J)
        DO 46 K=1,4
        G(I,J,K)=0.
        DO 46 JJ=1,4
        YM=0.5*(Y(I,J)+Y(I+1,J))
        RJM=0.5*(RJ(I,J)+RJ(I+1,J))
        G(I,J,K)=G(I,J,K)+A(K,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))/RJM*YM
   46   CONTINUE
   45   CONTINUE
      END IF
      IF(IMID.EQ.1.AND.I.EQ.IL) THEN
        DO 47 J=1,JL
        CALL JCBABPM(1,2,0,A,I,J)
        DO 48 K=1,4
        G(I,J,K)=0.
        DO 48 JJ=1,4
        YM=Y(I,J)
        RJM=RJ(I,J)
        G(I,J,K)=G(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I-1,J,JJ))/RJM*YM
   48   CONTINUE
   47   CONTINUE
      END IF
      RETURN
*****************************************************************
      ENTRY FLXFP(II,IMID)
*****************************************************************
*
```

```
*      +
*     F  FLUX VECTOR (IMID=0)
*
*       +  +
*     DF =B (I,J+1/2)*(Q(,J+1)-Q(I,J)) (IMID=1)
*
*****************************************************************
      I=II
      IF(IMID.EQ.0) THEN
        DO 50 J=1,JL
        CALL JCBABPM(2,1,0,A,I,J)
        DO 51 K=1,4
        F(I,J,K)=0.
        DO 51 JJ=1,4
        F(I,J,K)=F(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
  51    CONTINUE
  50    CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.NE.JL) THEN
        DO 55 J=1,JL1
        CALL JCBABPM(2,1,1,A,I,J)
        DO 56 K=1,4
        F(I,J,K)=0.
        DO 56 JJ=1,4
        YM=0.5*(Y(I,J)+Y(I,J+1))
        RJM=0.5*(RJ(I,J)+RJ(I,J+1))
        F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I,J+1,JJ)-Q(I,J,JJ))/RJM*YM
  56    CONTINUE
  55    CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.EQ.JL) THEN
        CALL JCBABPM(2,1,0,A,I,J)
        DO 58 K=1,4
        F(I,J,K)=0.
        DO 58 JJ=1,4
        YM=Y(I,J)
        RJM=RJ(I,J)
        F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I,J-1,JJ))/RJM*YM
  58    CONTINUE
      END IF
      RETURN
*****************************************************************
      ENTRY FLXFM(II,IMID)
*****************************************************************
*
*      -
*     F  FLUX VECTOR (IMID=0)
*
*       -  -
*     DF =B (I,J+1/2)*(Q(I,J+1)-Q(I,J))
*
*****************************************************************
      I=II
      IF(IMID.EQ.0) THEN
        DO 60 J=1,JL
```

```
        CALL JCBABPM(2,2,0,A,I,J)
        DO 61 K=1,4
        G(I,J,K)=0.
        DO 61 JJ=1,4
        G(I,J,K)=G(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
   61   CONTINUE
   60   CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.NE.JL) THEN
        DO 65 J=1,JL1
        CALL JCBABPM(2,2,1,A,I,J)
        DO 66 K=1,4
        G(I,J,K)=0.
        DO 66 JJ=1,4
        YM=0.5*(Y(I,J)+Y(I,J+1))
        RJM=0.5*(RJ(I,J)+RJ(I,J+1))
        G(I,J,K)=G(I,J,K)+A(K,JJ)*(Q(I,J+1,JJ)-Q(I,J,JJ))/RJM*YM
   66   CONTINUE
   65   CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.EQ.JL) THEN
        CALL JCBABPM(2,2,0,A,I,J)
        DO 68 K=1,4
        G(I,J,K)=0.
        DO 68 JJ=1,4
        YM=Y(I,J)
        RJM=RJ(I,J)
        G(I,J,K)=G(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I,J-1,JJ))/RJM*YM
   68   CONTINUE
      END IF
      RETURN
*****************************************************************
      ENTRY FLXSVS(II)
*****************************************************************
*
*     VISCOUS FLUX VECTOR, (DSVS'/DETA)+H''
*
*****************************************************************
*
*     VISCOUS FLUX VECTOR DSVS'/DETA
*
      I=II
      DO 70 J=2,JL1
      JP1=J+1
      JM1=J-1
      YJP=0.5*(Y(I,J)/RJ(I,J)+Y(I,JP1)/RJ(I,JP1))
      YJM=0.5*(Y(I,J)/RJ(I,J)+Y(I,JM1)/RJ(I,JM1))
      ZMUP=0.5*(ZMU(J)+ZMU(JP1))
      ZMUM=0.5*(ZMU(J)+ZMU(JM1))
      ZKP=0.5*(ZK(J)+ZK(JP1))
      ZKM=0.5*(ZK(J)+ZK(JM1))
      DUP=U(I,JP1)-U(I,J)
      DUM=U(I,J)-U(I,JM1)
      DVP=V(I,JP1)-V(I,J)
      DVM=V(I,J)-V(I,JM1)
```

```
      DU2P=U(I,JP1)**2-U(I,J)**2
      DU2M=U(I,J)**2-U(I,JM1)**2
      DV2P=V(I,JP1)**2-V(I,J)**2
      DV2M=V(I,J)**2-V(I,JM1)**2
      DUVP=U(I,JP1)*V(I,JP1)-U(I,J)*V(I,J)
      DUVM=U(I,J)*V(I,J)-U(I,JM1)*V(I,JM1)
      DTP=T(I,JP1)-T(I,J)
      DTM=T(I,J)-T(I,JM1)
      ZMUA1P=ZMUP*A1(I,J)
      ZMUA1M=ZMUM*A1(I,JM1)
      ZMUA2P=ZMUP*A2(I,J)
      ZMUA2M=ZMUM*A2(I,JM1)
      ZMUA3P=ZMUP*A3(I,J)
      ZMUA3M=ZMUM*A3(I,JM1)
      ZKA4P=ZKP*A4(I,J)
      ZKA4M=ZKM*A4(I,JM1)
      G(I,J,1)=0.
      G(I,J,2)=YJP*(ZMUA1P*DUP+ZMUA2P*DVP)
     >         -YJM*(ZMUA1M*DUM+ZMUA2M*DVM)
      G(I,J,3)=YJP*(ZMUA3P*DVP+ZMUA2P*DUP)
     >         -YJM*(ZMUA3M*DVP+ZMUA2M*DUM)
      G(I,J,4)=YJP*(0.5*ZMUA1P*DU2P+ZMUA2P*DUVP+0.5*ZMUA3P*DV2P
     >              +ZKA4P*DTP)
     >         -YJM*(0.5*ZMUA1M*DU2M+ZMUA2M*DUVM+0.5*ZMUA3M*DV2M
     >              +ZKA4M*DTM)
*
*     INSERT THE EXTRA FIRST ORDER TERMS IN CYLINDRICAL
*     COORDINATE SYSTEMS, VECTOR H''
*
*     H(1)=0.
*
*          1   2
*     H(2)=-*(--*ETA *D(MU*V)/DETA
*          J   3     X
*
*          1  2                    2
*     H(3)=-*(-*ETA *MU*DU/DETA --*V*ETA *DMU/DETA)
*          J  3     X              3       Y
*
*          1   2                         2
*     H(4)=-*(--*ETA *D(MU*U*V)/DETA --*ETA *D(MU*V*V)/DETA)
*          J   3     X                   3     Y
*
      EXJ=1./3.*ETAX(I,J)/RJ(I,J)
      EYJ=1./3.*ETAY(I,J)/RJ(I,J)
      G(I,J,2)=G(I,J,2)-EXJ*(ZMU(JP1)*V(I,JP1)-ZMU(JM1)*V(I,JM1))
      G(I,J,3)=G(I,J,3)+EXJ*ZMU(J)*(U(I,JP1)-U(I,JM1))
     >                  -EYJ*V(I,J)*(ZMU(JP1)-ZMU(JM1))
      G(I,J,4)=G(I,J,4)-EXJ*(ZMU(JP1)*U(I,JP1)*V(I,JP1)
     >                       -ZMU(JM1)*U(I,JM1)*V(I,JM1))
     >                  -EYJ*(ZMU(JP1)*V(I,JP1)**2
     >                       -ZMU(JM1)*V(I,JM1)**2)
   70 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RHSCL
*****************************************************************
*
*     RIGHT HAND SIDE CALCULATION
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EX1,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
     >        P0,T0,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
*****************************************************************
      ENTRY RHSEF(II)
*****************************************************************
*
*     RIGHT HAND SIDE CONVECTIVE EULER TERMS E, F
*
*     NOTE - SEE ALSO ENTRY RHSH FOR SOURCE CONVECTIVE TERM OF H'
*
*****************************************************************
      I=II
      DO 10 J=1,JL
      DO 10 K=1,4
      DQ(I,J,K)=0.
   10 CONTINUE
*
*     COMPUTE E(I-1,J), E(I+1,J), F(I,J-1), F(I,J+1) - 1ST ORDER
*
      CALL FLXE(I-1)
      IF(I.NE.IL) THEN
        CALL FLXE(I+1)
      ELSE
        CALL FLXE(I)
        CALL FLXE(I-2)
      END IF
      CALL FLXF(I)
      DO 20 J=2,JL
      DO 20 K=1,4
      IF(J.NE.JL) THEN
        IF(I.NE.IL) THEN
          DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I+1,J,K)-F(I-1,J,K))
     >                        +0.5*(G(I,J+1,K)-G(I,J-1,K))
        ELSE
```

```
          DQ(I,J,K)=DQ(I,J,K)+(F(I,J,K)-F(I-1,J,K))
     >                        +0.5*(G(I,J+1,K)-G(I,J-1,K))
     >              +0.5*(F(I,J,K)-2.0*F(I-1,J,K)+F(I-2,J,K))
            END IF
          ELSE
            IF(I.NE.IL) THEN
              DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I+1,J,K)-F(I-1,J,K))
     >                        +(G(I,J,K)-G(I,J-1,K))
     >              +0.5*(G(I,J,K)-2.0*G(I,J-1,K)+G(I,J-2,K))
            ELSE
              DQ(I,J,K)=DQ(I,J,K)+(F(I,J,K)-F(I-1,J,K))
     >                        +(G(I,J,K)-G(I,J-1,K))
     >              +0.5*(F(I,J,K)-2.0*F(I-1,J,K)+F(I-2,J,K))
     >              +0.5*(G(I,J,K)-2.0*G(I,J-1,K)+G(I,J-2,K))
            END IF
          END IF
   20   CONTINUE
*
*       COMPUTE D/E(I-1/2,J)/, D/E(I+1/2,J)/ - 1ST ORDER
*
          CALL FLXEP(I-1,1)
          CALL FLXEM(I-1,1)
          CALL FLXEP(I,1)
          CALL FLXEM(I,1)
          DO 30 J=2,JL
          DO 30 K=1,4
          IF(I.NE.IL) THEN
            DQ(I,J,K)=DQ(I,J,K)-0.5*(F(I,J,K)-F(I-1,J,K))
     >                        +0.5*(G(I,J,K)-G(I-1,J,K))
          ELSE
            DQ(I,J,K)=DQ(I,J,K)-(F(I,J,K)-F(I-1,J,K))
     >                        +(G(I,J,K)-G(I-1,J,K))
          END IF
   30   CONTINUE
*
*       COMPUTE D/F(I,J-1/2)/, D/F(I,J+1/2)/ - 1ST ORDER
*
          CALL FLXFP(I,1)
          CALL FLXFM(I,1)
          DO 35 J=2,JL
          DO 35 K=1,4
          IF(J.NE.JL) THEN
            DQ(I,J,K)=DQ(I,J,K)-0.5*(F(I,J,K)-F(I,J-1,K))
     >                        +0.5*(G(I,J,K)-G(I,J-1,K))
          ELSE
            DQ(I,J,K)=DQ(I,J,K)-(F(I,J,K)-F(I,J-1,K))
     >                        +(G(I,J,K)-G(I,J-1,K))
          END IF
   35   CONTINUE
*
*                  +     -
*       COMPUTE DE  , DE   - 2ND ORDER
*
          IF(I.GT.2.AND.I.LT.IL) THEN
            CALL FLXEP(I-2,1)
```

```
        CALL FLXEP(I-1,1)
        CALL FLXEM(I,1)
        CALL FLXEM(I+1,1)
      ELSE
      END IF
      DO 40 J=2,JL
      DO 40 K=1,4
      IF(I.EQ.2.OR.I.EQ.IL) GO TO 40
      IF(I.NE.IL-1) THEN
        DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I-1,J,K)-F(I-2,J,K))
     >                      -0.5*(G(I+1,J,K)-G(I,J,K))
      ELSE
        DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I-1,J,K)-F(I-2,J,K))
     >                      -(G(I+1,J,K)-G(I,J,K))
      END IF
   40 CONTINUE
*
*                +     -
*     COMPUTE DF  , DF   - 2ND ORDER
*
      CALL FLXFP(I,1)
      CALL FLXFM(I,1)
      DO 45 J=2,JL
      DO 45 K=1,4
      IF(J.EQ.2.OR.J.EQ.JL) GO TO 45
      IF(J.NE.JL-1) THEN
        DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I,J-1,K)-F(I,J-2,K))
     >                      -0.5*(G(I,J+1,K)-G(I,J,K))
      ELSE
        DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I,J-1,K)-F(I,J-2,K))
     >                      -(G(I,J+1,K)-G(I,J,K))
      END IF
   45 CONTINUE
      RETURN
*****************************************************************
      ENTRY RHSH(II)
*****************************************************************
*
*     SOURCE VECTOR H'
*
*     H(1)=0.
*     H(2)=0.
*     H(3)=(P-4./3.*MU*V/Y)/J
*     H(4)=0.
*
*****************************************************************
      I=II
      DO 50 J=2,JL
      IF(IVISC.EQ.0) THEN
        R2MY=0.
      ELSE
        R2MY=4./3.*ZMU(J)*V(I,J)/(RJ(I,J)*Y(I,J))
      END IF
      DQ(I,J,3)=DQ(I,J,3)-P(I,J)/RJ(I,J)+IVISC*R2MY
   50 CONTINUE
```

```
      RETURN
*****************************************************************
      ENTRY RHSVS(II)
*****************************************************************
*
*     RIGHT HAND SIDE VISCOUS TERMS
*
*     NOTE - SEE ALSO ENTRY RHSH FOR SOURCE VISCOUS TERMS OF H'
*
*****************************************************************
      I=II
      CALL FLXSVS(I)
      DO 90 J=2,JL1
      DO 90 K=2,4
      DQ(I,J,K)=DQ(I,J,K)-G(I,J,K)
   90 CONTINUE
      RETURN
      END
      SUBROUTINE SMOOTH
*****************************************************************
*
*     ADD ARTIFICIAL DISSIPATIONAL TERM FOR SAI, ETA - DIRECTION
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMW0,GAMMA0,REN,PRN,PRNT,TREF,ZMU0,OMEGA,
     >        P0,T0,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E0(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E0(1,1))
      DIMENSION ADD(4)
*****************************************************************
      ENTRY ADDX
*****************************************************************
*
*     ADD SAI-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
*
      COEF=0.1250*OMEGAX
      DO 70 J=1,JL
      DO 70 I=1,IL
      DO 70 I=2,IL
      IF(I.EQ.1) GO TO 10
      IF(I.EQ.2) GO TO 20
      IF(I.EQ.IL1) GO TO 30
```

```
      IF(I.EQ.IL) GO TO 40
      DO 5 K=1,4
    5 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >        +6.*Q(I,J,K)-4.*Q(I-1,J,K)
     >        +Q(I-2,J,K))
      GO TO 50
   10 DO 15 K=1,4
      QM=2.*Q(1,J,K)-Q(2,J,K)
      QMM=2.*QM-Q(1,J,K)
   15 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >        +6.*Q(I,J,K)-4.*QM+QMM)
      GO TO 50
   20 DO 25 K=1,4
      QMM=2.*Q(1,J,K)-Q(2,J,K)
   25 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
     >        +6.*Q(I,J,K)-4.*Q(I-1,J,K)
     >        +QMM)
      GO TO 50
   30 DO 35 K=1,4
      QPP=2.*Q(I+1,J,K)-Q(I,J,K)
   35 ADD(K)=COEF*(QPP-4.*Q(I+1,J,K)+6.*Q(I,J,K)
     >        -4.*Q(I-1,J,K)+Q(I-2,J,K)
     >        )
      GO TO 50
   40 DO 45 K=1,4
      QP=2.*Q(I,J,K)-Q(I-1,J,K)
      QPP=2.*QP-Q(I,J,K)
   45 ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
     >       Q(I-1,J,K)+Q(I-2,J,K))
   50 CONTINUE
      DO 60 K=1,4
   60 DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
   70 CONTINUE
      RETURN
*****************************************************************
      ENTRY ADDY
*****************************************************************
*
*     ADD ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
*
      COEF=0.1250*OMEGAY
      DO 170 I=1,IL
      DO 170 I=2,IL
      DO 170 J=1,JL
      IF(J.EQ.1) GO TO 110
      IF(J.EQ.2) GO TO 120
      IF(J.EQ.JL1) GO TO 130
      IF(J.EQ.JL) GO TO 140
      DO 105 K=1,4
  105 ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >     +6.*Q(I,J,K)-4.*Q(I,J-1,K)
     >     +Q(I,J-2,K))
      GO TO 150
  110 DO 115 K=1,4
      QM=2.*Q(I,1,K)-Q(I,2,K)
```

```
      QMM=2.*QM-Q(I,1,K)
  115 ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >     +6.*Q(I,J,K)-4.*QM+QMM)
      GO TO 150
  120 DO 125 K=1,4
      QMM=2.*Q(I,1,K)-Q(I,2,K)
  125 ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
     >  +6.*Q(I,J,K)-4.*Q(I,J-1,K)
     >   +QMM)
      GO TO 150
  130 DO 135 K=1,4
      QPP=2.*Q(I,J+1,K)-Q(I,J,K)
  135 ADD(K)=COEF*(QPP-4.*Q(I,J+1,K)+6.*Q(I,J,K)
     >  -4.*Q(I,J-1,K)+Q(I,J-2,K)
     >  )
      GO TO 150
  140 DO 145 K=1,4
      QP=2.*Q(I,J,K)-Q(I,J-1,K)
      QPP=2.*QP-Q(I,J,K)
  145 ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
     >  Q(I,J-1,K)+Q(I,J-2,K))
  150 CONTINUE
      DO 160 K=1,4
  160 DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
  170 CONTINUE
      RETURN
      END
      SUBROUTINE UGAS3(E,RHO,ZMU)

      INPUTS FOR SUBROUTINE :

      E = SPECIFIC INTERNAL ENERGY, IN (M/S)**2
      RHO = DENSITY, IN KG/M**3

      OUTPUT :

      ZMU = DYNAMIC VISCOSITY, IN KG/M/S

      DATA RHO0,E0/1.243,78408.4E00/
      Z=ALOG10(E/E0)
      Y=ALOG10(RHO/RHO0)
      IF (Z.GT.0.67E00) GO TO 10
      GAS1=4.84547E-01+4.67135E-01*Z
      GAS2=(5.71205E-04-1.43629E-03*Z)*Y
      GAS3=(2.55110E00-2.33472E-04*Y-1.44102E00*Z)*Z*Z
      GAS4=(2.53416E-04-4.72375E-04*Z+1.86899E-05*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 90
   10 IF (Z.GT.1.75E00) GO TO 20
      GAS1=-3.71666E01+6.67883E01*Z
      GAS2=(-2.43998E00+2.12309E00*Z)*Y
      GAS3=(-3.69259E01-3.08426E-01*Y+7.36486E00*Z)*Z*Z
      GAS4=(-1.46446E-01+7.54423E-02*Z-2.91464E-03*Y)*Y*Y
      GAS5=3.61757E01-6.11102E01*Z
      GAS6=(2.40531E00-2.05914E00*Z)*Y
```

```
      GAS7=(3.23911E01+2.79149E-01*Y-5.07640E00*Z)*Z*Z
      GAS8=(1.37916E-01-6.72041E-02*Z+2.61987E-03*Y)*Y*Y
      GAS9=EXP(-3.433E01-1.823E00*Y+2.499E01*Z+6.503E-01*Z*Y)
      GO TO 80
   20 IF (Z.GT.2.50E00) GO TO 30
      GAS1=-1.65147E02+2.11028E02*Z
      GAS2=(-4.70948E00+2.78258E00*Z)*Y
      GAS3=(-8.78308E01-1.28671E-01*Y+1.27639E01*Z)*Z*Z
      GAS4=(-3.19867E-01+1.73179E-01*Z+3.86106E-03*Y)*Y*Y
      GAS5=2.30407E02-2.98055E02*Z
      GAS6=(-6.18307E00+8.44595E00*Z)*Y
      GAS7=(1.26933E02-2.61671E00*Y-1.77257E01*Z)*Z*Z
      GAS8=(-2.30229E-02+2.25458E-02*Z-4.41072E-03*Y)*Y*Y
      GAS9=EXP(-6.882E01+8.824E00*Y+3.203E01*Z-5.359E00*Z*Y)
      GO TO 80
   30 IF (Z.GT.2.85E00) GO TO 40
      GAS1=-7.09274E03+7.13648E03*Z
      GAS2=(-2.46014E02+1.65826E02*Z)*Y
      GAS3=(-2.37952E03-2.75487E01*Y+2.63465E02*Z)*Z*Z
      GAS4=(-3.49744E00+1.28641E00*Z-3.13711E-03*Y)*Y*Y
      GAS5=5.26158E03-4.96701E03*Z
      GAS6=(2.03138E02-1.32984E02*Z)*Y
      GAS7=(1.52424E03+2.15081E01*Y-1.50450E02*Z)*Z*Z
      GAS8=(3.32432E00-1.15997E00*Z+1.14862E-02*Y)*Y*Y
      GAS9=EXP(-3.594E02-3.763E01*Y+1.319E02*Z+1.348E01*Z*Y)
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 80
   40 IF (Z.GT.3.15E00) GO TO 50
      GAS1=-1.27748E03+1.29400E03*Z
      GAS2=(-3.60724E01+2.63194E01*Z)*Y
      GAS3=(-4.22958E02-4.38228E00*Y+4.50571E01*Z)*Z*Z
      GAS4=(-4.74425E-01+2.89684E-01*Z+1.64048E-02*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 90
   50 IF (Y.GT.-3.80E00) GO TO 70
      IF (Z.GT.3.19E00) GO TO 60
      GAS1=4.55919E03-4.21057E03*Z
      GAS2=(1.03001E01-2.63478E01*Z)*Y
      GAS3=(1.29069E03+6.59587E00*Y-1.31413E02*Z)*Z*Z
      GAS4=(-8.28137E00+1.9827E00*Z-1.7287E-01*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 90
   60 Z=E/E0
      GAS1=-4.41792E02+9.7986E-02*Z
      GAS2=(-3.03148E02+7.6065E-03*Z)*Y
      GAS3=(-5.5711E-05-3.52836E-06*Y+8.86148E-09*Z)*Z*Z
      GAS4=(-7.561E01-4.76816E-04*Z-6.48859E00*Y)*Y*Y
      GAS5=6.72387E04+3.28398E00*Z
      GAS6=(3.55009E04+2.72616E00*Z)*Y
      GAS7=(2.13714E-03+3.42377E-04*Y-6.84897E-08*Z)*Z*Z
      GAS8=(6.50886E03+3.8056E-01*Z+4.14116E02*Y)*Y*Y
      GAS9=EXP(2.978E01+5.415E00*Y+1.713E-03*Z+3.115E-04*Y*Z)
      F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
      GO TO 90
   70 GAS1=-6.4029E03+6.24254E03*Z
```

```
      GAS2=(1.03279E02-8.73181E01*Z)*Y
      GAS3=(-2.02865E03+1.71878E01*Y+2.19907E02*Z)*Z*Z
      GAS4=(-1.22397E01+3.57830E00*Z-1.27953E-01*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 90
   80 F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0+GAS9)
   90 ZMU=1.748583E-05*F
      RETURN
      END
      SUBROUTINE UGAS4(E,RHO,ZK)

      INPUTS FOR SUBROUTINE :

      E = SPECIFIC INTERNAL ENERGY, IN (M/S)**2
      RHO = DENSITY, IN KG/M**3

      OUTPUT :

      ZK = COEFFICIENT OF THERMAL CONDUCTIVITY, IN J/(KELVIN*M*S)

      DATA RHO0,E0/1.243E00,78408E00/
      Z=ALOG10(E/E0)
      Y=ALOG10(RHO/RHO0)
      IF (Z.GT.0.65E00) GO TO 10
      GAS1=1.8100369E-01+4.8126802E00*Z
      GAS2=(-2.7231116E-02+1.2691337E-01*Z)*Y
      GAS3=(-8.9913034E00-1.2624085E-01*Y+8.9649105E00*Z)*Z*Z
      GAS4=(-4.7198236E-03+9.2328079E-03*Z-2.9488327E-04*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 200
   10 IF (Y.GT.-1.00E00) GO TO 130
      IF (Y.GT.-3.00E00) GO TO 70
      IF (Z.GT.1.25E00) GO TO 20
      GAS1=-1.05935E04+2.31470E04*Z
      GAS2=(-7.41294E02+1.21724E03*Z)*Y
      GAS3=(-1.67601E04-4.43184E02*Y+4.06631E03*Z)*Z*Z
      GAS4=(1.35105E01+4.94914E00*Z+1.55386E00*Y)*Y*Y
      GAS5=1.06032E04-2.31560E04*Z
      GAS6=(7.46951E02-1.22465E03*Z)*Y
      GAS7=(1.67604E04+4.45919E02*Y-4.06258E03*Z)*Z*Z
      GAS8=(-1.28615E01-5.32398E00*Z-1.52956E00*Y)*Y*Y
      GAS9=EXP(-4.219E01-4.687E00*Y+2.812E01*Z+3.125E00*Y*Z)
      F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
      GO TO 200
   20 IF (Z.GT.1.775E00) GO TO 30
      GAS1=3.79375E03-7.40351E03*Z
      GAS2=(3.29698E02-3.55916E02*Z)*Y
      GAS3=(4.77122E03+1.00241E02*Y-1.00740E03*Z)*Z*Z
      GAS4=(1.97061E01-8.42554E00*Z+4.80494E-01*Y)*Y*Y
      GAS5=-4.53603E03+9.05605E03*Z
      GAS6=(-4.95870E02+6.33563E02*Z)*Y
      GAS7=(-5.95317E03-2.05442E02*Y+1.28945E03*Z)*Z*Z
      GAS8=(-2.00087E01+1.18851E01*Z-1.71735E-01*Y)*Y*Y
      GAS9=EXP(-3.318E01+3.158E-01*Y+1.863E01*Z-1.035E00*Y*Z)
      GO TO 190
```

```
 30 IF (Z.GT.1.93E00) GO TO 40
    GAS1=2.06651875E05-3.165645E05*Z
    GAS2=(-3.07322021E02+4.57036377E02*Z)*Y
    GAS3=(1.61824937E05-1.55508453E02*Y-2.7603957E04*Z)*Z*Z
    GAS4=(1.92260265E00-2.24788094E00*Z-3.06226015E-01*Y)*Y*Y
    GAS5=-2.06564312E05+3.18191312E05*Z
    GAS6=(2.17542285E03-2.46670776E03*Z)*Y
    GAS7=(-1.63597062E05+7.16753174E02*Y+2.80926367E04*Z)*Z*Z
    GAS8=(3.39526825E01-7.538[6645E00*Z+1.91214371E00*Y)*Y*Y
    GAS9=EXP(-3.924E02-5.206E01*Y+2.054E02*Z+2.679E01*Y*Z)
    GO TO 190
 40 IF (Z.GT.2.60E00) GO TO 50
    GAS1=7.1572625E04-9.2471625E04*Z
    GAS2=(1.9646323E03-2.0280527E03*Z)*Y
    GAS3=(3.9446105E04+4.5673853E02*Y-5.5728672E03*Z)*Z*Z
    GAS4=(-9.2131958E01+1.2724541E01*Z-5.0568476E00*Y)*Y*Y
    GAS5=-3.2910781E04+4.2551211E04*Z
    GAS6=(1.4566331E03-2.2653745E03*Z)*Y
    GAS7=(-1.9476277E04+8.4370288E02*Y+3.2389702E03*Z)*Z*Z
    GAS8=(-1.3324594E02+1.0591533E02*Z+5.8639469E00*Y)*Y*Y
    GAS9=EXP(4.917E01+2.415E01*Y-2.455E01*Z-1.181E01*Y*Z)
    GO TO 190
 50 IF (Z.GT.2.69E00) GO TO 60
    GAS1=1.145683E06-1.237525E06*Z
    GAS2=(1.4024508E04-9.3467227E03*Z)*Y
    GAS3=(4.4593056E05+1.533074E03*Y-5.3608352E04*Z)*Z*Z
    GAS4=(2.8485107E02-1.0968916E02*Z-1.0955791E00*Y)*Y*Y
    GAS5=-1.752087E06+1.79675E06*Z
    GAS6=(-1.3278737E05+9.8215562E04*Z)*Y
    GAS7=(-6.0791744E05-1.811943E04*Y+6.7709875E04*Z)*Z*Z
    GAS8=(-1.3384084E03+5.2707324E02*Z+2.5904894E00*Y)*Y*Y
    GAS9=EXP(-1.798E02+7.371E00*Y+6.731E01*Z-3.205E00*Y*Z)
    GO TO 190
 60 GAS1=-8.5499625E04+1.1739656E05*Z
    GAS2=(6.4563168E04-3.9551203E04*Z)*Y
    GAS3=(-4.8170254E04+6.0816055E03*Y+6.2052031E03*Z)*Z*Z
    GAS4=(2.3473167E-01+1.8871567E01*Z+4.0757723E00*Y)*Y*Y
    GAS5=5.8546883E04-9.4634875E04*Z
    GAS6=(-6.6513812E04+4.0899945E04*Z)*Y
    GAS7=(4.2127227E04-6.3717305E03*Y-5.7495195E03*Z)*Z*Z
    GAS8=(-1.0260344E00-5.343277E01*Z-1.1017392E01*Y)*Y*Y
    GAS9=EXP(5.411E00+1.162E01*Y-1.082E00*Z-3.391E00*Y*Z)
    F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS6)/(1.0-GAS9)
    GO TO 200
 70 IF (Z.GT.1.29E00) GO TO 80
    GAS1=-1.22493E04+2.41071E04*Z
    GAS2=(-1.61829E03+2.22535E03*Z)*Y
    GAS3=(-1.59261E04-7.53213E02*Y+3.53376E03*Z)*Z*Z
    GAS4=(1.98026E00+5.18483E00*Z+1.47851E00*Y)*Y*Y
    GAS5=1.22486E04-2.41023E04*Z
    GAS6=(1.61810E03-2.22571E03*Z)*Y
    GAS7=(1.59235E04+7.53746E02*Y-3.53168E03*Z)*Z*Z
    GAS8=(-2.15482E00-5.05115E00*Z-1.48795E00*Y)*Y*Y
    GAS9=EXP(-3.111E01-4.444E00*Y+1.944E01*Z+2.778E00*Y*Z)
    F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
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```
      GO TO 200
   80 IF (Z.GT.1.85E00) GO TO 90
      GAS1=3.18060E03-6.69664E03*Z
      GAS2=(4.33382E01-2.14649E02*Z)*Y
      GAS3=(4.41377E03+9.41359E01*Y-9.29758E02*Z)*Z*Z
      GAS4=(-3.62190E01+1.15538E01*Z-2.14621E00*Y)*Y*Y
      GAS5=-5.98764E03+1.29243E04*Z
      GAS6=(-2.72261E02+5.42378E02*Z)*Y
      GAS7=(-9.03293E03-2.11787E02*Y+2.07831E03*Z)*Z*Z
      GAS8=(2.74179E01-5.68578E00*Z+1.91217E00*Y)*Y*Y
      GAS9=EXP(-1.854E01+7.11E00*Y+1.068E01*Z-5.449E00*Y*Z)
      GO TO 190
   90 IF (Z.GT.2.0E00) GO TO 100
      GAS1=5.14024E04-7.52733E04*Z
      GAS2=(-3.30889E02+3.11550E02*Z)*Y
      GAS3=(3.66539E04-7.41227E01*Y-5.93015E03*Z)*Z*Z
      GAS4=(-4.84164E01+2.23133E01*Z-9.19118E-01*Y)*Y*Y
      GAS5=-1.80898E05+2.82532E05*Z
      GAS6=(-1.01053E03+9.75576E02*Z)*Y
      GAS7=(-1.47220E05-2.33631E02*Y+2.55940E04*Z)*Z*Z
      GAS8=(3.28681E00-1.76588E00*Z-1.54962E-01*Y)*Y*Y
      GAS9=EXP(-4.104E01+6.507E01*Y+2.083E01*Z-3.472E01*Z*Y)
      GO TO 190
  100 IF (Z.GT.2.58E00) GO TO 110
      GAS1=5.1131824E04-6.664875E04*Z
      GAS2=(2.02171E03-1.9306292E03*Z)*Y
      GAS3=(2.8762395E04+4.3353467E02*Y-4.1064609E03*Z)*Z*Z
      GAS4=(-8.4970047E01+1.7925919E01*Z-6.2576542E00*Y)*Y*Y
      GAS5=-6.2768156E04+8.6015875E04*Z
      GAS6=(-1.0002036E03+6.2537280E02*Z)*Y
      GAS7=(-3.957827E04-3.8467377E01*Y+6.12953E03*Z)*Z*Z
      GAS8=(-1.0591702E02+7.636142E01*Z+5.938859E00*Y)*Y*Y
      GAS9=EXP(-3.901E00+2.418E01*Y+1.374E00*Z-1.145E01*Y*Z)
      GO TO 190
  110 IF (Z.GT.2.73E00) GO TO 120
      GAS1=1.0088046E06-1.086321E06*Z
      GAS2=(1.3844801E04-9.7268516E03*Z)*Y
      GAS3=(3.8985325E05+1.7091665E03*Y-4.6621066E04*Z)*Z*Z
      GAS4=(1.4840726E02-5.2645004E01*Z-1.5477133E-01*Y)*Y*Y
      GAS5=-1.073351E06+1.14571E06*Z
      GAS6=(-1.9343957E04+1.3366211E04*Z)*Y
      GAS7=(-4.0670987E05-2.2955198E03*Y+4.7999871E04*Z)*Z*Z
      GAS8=(-4.1016724E02+1.4994148E02*Z-1.9779787E00*Y)*Y*Y
      GAS9=EXP(-1.026E02+6.302E01*Y+3.819E01*Z-2.431E01*Y*Z)
      GO TO 190
  120 GAS1=-9.6638500E04+1.3206488E04*Z
      GAS2=(-4.7458105E04+2.3596875E04*Z)*Y
      GAS3=(1.8602773E04-2.306802E03*Y-4.0413552E03*Z)*Z*Z
      GAS4=(-5.3564258E03+2.2433904E03*Z+2.5188145E02*Y)*Y*Y
      GAS5=1.0962581E05-2.990116E04*Z
      GAS6=(4.7883496E04-2.3785383E04*Z)*Y
      GAS7=(-1.1753969E04+2.2905522E03*Y+3.1304399E03*Z)*Z*Z
      GAS8=(5.473418E03-2.3208018E03*Z-2.6570068E02*Y)*Y*Y
      GAS9=EXP(-3.107E01+1.082E01*Y+1.047E01*Z-3.047E00*Y*Z)
      F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
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      GO TO 200
  130 IF (Z.GT.1.40E00) GO TO 140
      GAS1=-1.58386E03+3.49223E03*Z
      GAS2=(-8.39834E02+1.09565E03*Z)*Y
      GAS3=(-2.56175E03-3.56197E02*Y+6.25145E02*Z)*Z*Z
      GAS4=(-1.22407E01+7.65634E00*Z+2.58235E-01*Y)*Y*Y
      GAS5=1.58025E03-3.47664E03*Z
      GAS6=(8.39588E02-1.09490E03*Z)*Y
      GAS7=(2.54682E03+3.55674E02*Y-6.18504E02*Z)*Z*Z
      GAS8=(1.20843E01-7.44857E00*Z-2.91202E-01*Y)*Y*Y
      GAS9=EXP(-2.171E01-4.342E00*Y+1.316E01*Z+2.632E00*Y*Z)
      F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
      GO TO 200
  140 IF (Z.GT.1.91E00) GO TO 150
      GAS1=7.89255E02-1.91743E03*Z
      GAS2=(3.59227E02-4.44070E02*Z)*Y
      GAS3=(1.39463E03+1.34083E02*Y-3.13446E02*Z)*Z*Z
      GAS4=(1.90681E01-1.09285E01*Z+4.24933E-02*Y)*Y*Y
      GAS5=-1.31401E03+3.13134E03*Z
      GAS6=(-5.18755E02+6.80268E02*Z)*Y
      GAS7=(-2.32493E03-2.21393E02*Y+5.52563E02*Z)*Z*Z
      GAS8=(-3.32001E01+2.11819E01*Z-4.75163E-01*Y)*Y*Y
      GAS9=EXP(-5.025E01-8.412E00*Y+2.982E01*Z+3.509E00*Y*Z)
      GO TO 190
  150 IF (Z.GT.2.05E00) GO TO 160
      GAS1=3.58691E04-5.16852E04*Z
      GAS2=(-6.30189E02+6.63314E02*Z)*Y
      GAS3=(2.47471E04-1.73538E02*Y-3.93167E03*Z)*Z*Z
      GAS4=(-4.23871E01+2.08048E01*Z-1.05512E00*Y)*Y*Y
      GAS5=-1.10522E05+1.67591E05*Z
      GAS6=(4.61877E03-4.94930E03*Z)*Y
      GAS7=(-8.46558E04+1.32441E03*Y+1.42438E04*Z)*Z*Z
      GAS8=(2.25065E01-1.10316E01*Z+9.62887E-01*Y)*Y*Y
      GAS9=EXP(-1.681E02+7.063E01*Y+8.75E01*Z-3.75E01*Y*Z)
      GO TO 190
  160 IF (Z.GT.2.57E00) GO TO 170
      GAS1=3.1899562E04-4.2186664E04*Z
      GAS2=(2.3055603E03-1.9897017E03*Z)*Y
      GAS3=(1.849998E04+4.2561816E02*Y-2.6808696E03*Z)*Z*Z
      GAS4=(-1.6195114E01+5.8640623E00*Z-3.6172504E00*Y)*Y*Y
      GAS5=-5.7594039E04+7.9328437E04*Z
      GAS6=(-1.9275989E03+1.6730544E03*Z)*Y
      GAS7=(-3.6473008E04-3.6100732E02*Y+5.597543E03*Z)*Z*Z
      GAS8=(-7.920808E01+4.0542084E01*Z+2.1495867E00*Y)*Y*Y
      GAS9=EXP(-5.733E01+2.088E01*Y+2.592E01*Z-9.793E00*Y*Z)
      GO TO 190
  170 IF (Z.GT.2.75E00) GO TO 180
      GAS1=7.0838087E05-7.5619919E05*Z
      GAS2=(3.9503091E03-2.7381802E03*Z)*Y
      GAS3=(2.6888181E05+4.7728687E02*Y-3.183816E04*Z)*Z*Z
      GAS4=(-1.2532251E02+4.7734787E01*Z-4.0148029E00*Y)*Y*Y
      GAS5=-2.5216325E05+2.1727769E05*Z
      GAS6=(9.2882383E03-7.780918E03*Z)*Y
      GAS7=(-5.6539297E04+1.6120212E03*Y+3.9419248E03*Z)*Z*Z
      GAS8=(1.8537296E02-7.1010757E01*Z+1.1307096E00*Y)*Y*Y
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      GAS9=EXP(-1.786E02+2.18E-01*Y+6.714E01*Z-4.739E-01*Y*Z)
      GO TO 190
  180 GAS1=3.1855037E05-3.3041156E05*Z
      GAS2=(2.2983352E04-1.6623461E04*Z)*Y
      GAS3=(1.13848E05+3.0098223E03*Y-1.3020133E04*Z)*Z*Z
      GAS4=(-1.8599039E02+6.9840683E01*Z-7.7371645E00*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 200
  190 F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0+GAS9)
  200 ZK=1.87915E-02*F
      RETURN
      END
      FUNCTION FAMW(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      IF(R.LT.X1(1)) II=1
      IF(R.GT.X1(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X1(I).AND.R.LE.X1(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
    1 CONTINUE
    2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X1(1),X1(9)
  500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FAMW'/
     >  2X,'R=',E12.5,2X,'X1(1)=',E12.5,2X,'X1(9)=',E12.5)
        STOP
      ELSE
      END IF
      IF(T.LT.Y1(1)) JJ=1
      IF(T.GT.Y1(8)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y1(J).AND.T.LE.Y1(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
    3 CONTINUE
    4 CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) T,Y1(1),Y1(9)
  501   FORMAT(//2X,'T IS OUT OF BOUNDARIES, CALLED FROM FAMW'/
     >  2X,'T=',E12.5,2X,'Y1(1)=',E12.5,2X,'Y1(9)=',E12.5)
        STOP
      ELSE
      END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
```

```
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      AMW1=F1(I,J)
     >     +(F1(I+1,J)-F1(I,J))/(X1(I+1)-X1(I))*(R-X1(I))
      AMW2=F1(I,J+1)
     >     +(F1(I+1,J+1)-F1(I,J+1))/(X1(I+1)-X1(I))*(R-X1(I))
      AMW=AMW1+(AMW2-AMW1)/(Y1(J+1)-Y1(J))*(T-Y1(J))
      FAMW=AMW
      RETURN
      END
      FUNCTION FE(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      IF(R.LT.X4(1)) II=0
      IF(R.GT.X4(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X4(I).AND.R.LE.X4(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
    1 CONTINUE
    2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X4(1),X4(9)
  500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FE'/
     >  2X,'R=',E12.5,2X,'X4(1)=',E12.5,2X,'X4(9)=',E12.5)
        STOP
      ELSE
      END IF
      IF(T.LT.Y4(1)) JJ=0
      IF(T.GT.Y4(9)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y4(J).AND.T.LE.Y4(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
    3 CONTINUE
    4 CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) T,Y4(1),Y4(9)
  501   FORMAT(//2X,'T IS OUT OF BOUNDARIES, CALLED FROM FE'/
     >  2X,'T=',E12.5,2X,'Y4(1)=',E12.5,2X,'Y4(9)=',E12.5)
        STOP
      ELSE
      END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
```

```
      E1=F4(I,J)
     >  +(F4(I+1,J)-F4(I,J))/(X4(I+1)-X4(I))*(R-X4(I))
      IF(E1.LT.F4(1,J)) E1=F4(1,J)
      IF(E1.GT.F4(9,J)) E1=F4(9,J)
      E2=F4(I,J+1)
     >  +(F4(I+1,J+1)-F4(I,J+1))/(X4(I+1)-X4(I))*(R-X4(I))
      IF(E2.LT.F4(1,J+1)) E2=F4(1,J+1)
      IF(E2.GT.F4(9,J+1)) E2=F4(9,J+1)
      E=E1+(E2-E1)/(Y4(J+1)-Y4(J))*(T-Y4(J))
      IF(E.LT.F4(I,1)) E=F4(I,1)
      IF(E.GT.F4(I,9)) E=F4(I,9)
      FE=E
      RETURN
      END
      FUNCTION FT(R,E)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      IF(R.LT.X5(1)) II=0
      IF(R.GT.X5(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X5(I).AND.R.LE.X5(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
    1 CONTINUE
    2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X5(1),X5(9)
  500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FT'/
     >  2X,'R=',E12.5,2X,'X5(1)=',E12.5,2X,'X5(9)=',E12.5)
        STOP
      ELSE
      END IF
      IF(E.LT.Y5(1)) JJ=0
      IF(E.GT.Y5(9)) JJ=8
      DO 3 J=1,8
      IF(E.GE.Y5(J).AND.E.LE.Y5(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
    3 CONTINUE
    4 CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) E,Y5(1),Y5(9)
  501   FORMAT(//2X,'E IS OUT OF BOUNDARIES, CALLED FROM FT'/
     >  2X,'E=',E12.5,2X,'Y5(1)=',E12.5,2X,'Y5(9)=',E12.5)
        STOP
      ELSE
      END IF
      I=II
      J=JJ
```

```
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      T1=F5(I,J)
     >  +(F5(I+1,J)-F5(I,J))/(X5(I+1)-X5(I))*(R-X5(I))
      T2=F5(I,J+1)
     >  +(F5(I+1,J+1)-F5(I,J+1))/(X5(I+1)-X5(I))*(R-X5(I))
      T=T1+(T2-T1)/(Y5(J+1)-Y5(J))*(E-Y5(J))
      FT=T
      RETURN
      END
      FUNCTION FZMU(R,E)
      CALL UGAS3(E,R,ZMU)
      FZMU=ZMU
      RETURN
      END
      FUNCTION FZK(R,E)
      CALL UGAS4(E,R,ZK)
      FZK=ZK
      RETURN
      END
      FUNCTION FDMDRT(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      IF(R.LT.X2(1)) II=0
      IF(R.GT.X2(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X2(I).AND.R.LE.X2(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
    1 CONTINUE
    2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X2(1),X2(9)
  500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDMDRT'/
     >  2X,'R=',E12.5,2X,'X2(1)=',E12.5,2X,'X2(9)=',E12.5)
        STOP
      ELSE
      END IF
      IF(T.LT.Y2(1)) JJ=0
      IF(T.GT.Y2(9)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y2(J).AND.T.LE.Y2(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
    3 CONTINUE
    4 CONTINUE
      IF(JJ.EQ.0) THEN
```

```
      WRITE (6,501) T,Y2(1),Y2(9)
501   FORMAT(//2X,'T IS OUT OF BOUNDARIES, CALLED FROM FDMDRT'/
     > 2X,'T=',E12.5,2X,'Y2(1)=',E12.5,2X,'Y2(9)=',E12.5)
      STOP
     ELSE
     END IF
     I=II
     J=JJ
     IF(II.EQ.0) I=II+1
     IF(II.EQ.8) I=II-1
     IF(JJ.EQ.0) J=JJ+1
     IF(JJ.EQ.8) J=JJ-1
     DMDRT1=F2(I,J)
     > +(F2(I+1,J)-F2(I,J))/(X2(I+1)-X2(I))*(R-X2(I))
     DMDRT2=F2(I,J+1)
     > +(F2(I+1,J+1)-F2(I,J+1))/(X2(I+1)-X2(I))*(R-X2(I))
     DMDRT=DMDRT1+(DMDRT2-DMDRT1)/(Y2(J+1)-Y2(J))*(T-Y2(J))
     FDMDRT=DMDRT
     RETURN
     END
     FUNCTION FDMDTR(R,T)
     COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >             X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >             X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >             X7(9),Y7(9),F7(9,9)
     IF(R.LT.X3(1)) II=0
     IF(R.GT.X3(9)) II=8
     DO 1 I=1,8
     IF(R.GE.X3(I).AND.R.LE.X3(I+1)) THEN
       II=I
       GO TO 2
     ELSE
     END IF
   1 CONTINUE
   2 CONTINUE
     IF(II.EQ.0) THEN
       WRITE (6,500) R,X3(1),X3(9)
500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDMDTR'/
     > 2X,'R=',E12.5,2X,'X3(1)=',E12.5,2X,'X3(9)=',E12.5)
       STOP
     ELSE
     END IF
     IF(T.LT.Y3(1)) JJ=0
     IF(T.GT.Y3(9)) JJ=8
     DO 3 J=1,8
     IF(T.GE.Y3(J).AND.T.LE.Y3(J+1)) THEN
       JJ=J
       GO TO 4
     ELSE
     END IF
   3 CONTINUE
   4 CONTINUE
     IF(JJ.EQ.0) THEN
       WRITE (6,501) T,Y3(1),Y3(9)
501   FORMAT(//2X,'T IS OUT OF BOUNDARIES, CALLED FROM FDMDTR'/
```

```
     >  2X,'T=',E12.5,2X,'Y3(1)=',E12.5,2X,'Y3(9)=',E12.5)
        STOP
      ELSE
      END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      DMDTR1=F3(I,J)
     >  +(F3(I+1,J)-F3(I,J))/(X3(I+1)-X3(I))*(R-X3(I))
      DMDTR2=F3(I,J+1)
     >  +(F3(I+1,J+1)-F3(I,J+1))/(X3(I+1)-X3(I))*(R-X3(I))
      DMDTR=DMDTR1+(DMDTR2-DMDTR1)/(Y3(J+1)-Y3(J))*(T-Y3(J))
      FDMDTR=DMDTR
      RETURN
      END
      FUNCTION FDTDRE(R,E)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      IF(R.LT.X6(1)) II=0
      IF(R.GT.X6(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X6(I).AND.R.LE.X6(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
    1 CONTINUE
    2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X6(1),X6(9)
  500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDTDRE'/
     >  2X,'R=',E12.5,2X,'X6(1)=',E12.5,2X,'X6(9)=',E12.5)
        STOP
      ELSE
      END IF
      IF(E.LT.Y6(1)) JJ=0
      IF(E.GT.Y6(9)) JJ=8
      DO 3 J=1,8
      IF(E.GE.Y6(J).AND.E.LE.Y6(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
    3 CONTINUE
    4 CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) E,Y6(1),Y6(9)
  501   FORMAT(//2X,'E IS OUT OF BOUNDARIES, CALLED FROM FDTDRE'/
     >  2X,'E=',E12.5,2X,'Y6(1)=',E12.5,2X,'Y6(9)=',E12.5)
        STOP
```

```
      ELSE
      END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      DTDRE1=F6(I,J)
     >  +(F6(I+1,J)-F6(I,J))/(X6(I+1)-X6(I))*(R-X6(I))
      DTDRE2=F6(I,J+1)
     >  +(F6(I+1,J+1)-F6(I,J+1))/(X6(I+1)-X6(I))*(R-X6(I))
      DTDRE=DTDRE1+(DTDRE2-DTDRE1)/(Y6(J+1)-Y6(J))*(E-Y6(J))
      FDTDRE=DTDRE
      RETURN
      END
      FUNCTION FDTDER(R,E)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
     >              X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
     >              X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
     >              X7(9),Y7(9),F7(9,9)
      IF(R.LT.X7(1)) II=0
      IF(R.GT.X7(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X7(I).AND.R.LE.X7(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
    1 CONTINUE
    2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X7(1),X7(9)
  500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDTDER'/
     >  2X,'R=',E12.5,2X,'X7(1)=',E12.5,2X,'X7(9)=',E12.5)
        STOP
      ELSE
      END IF
      IF(E.LT.Y7(1)) JJ=0
      IF(E.GT.Y7(9)) JJ=8
      DO 3 J=1,8
      IF(E.GE.Y7(J).AND.E.LE.Y7(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
    3 CONTINUE
    4 CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) E,Y7(1),Y7(9)
  501   FORMAT(//2X,'E IS OUT OF BOUNDARIES, CALLED FROM FDTDER'/
     >  2X,'E=',E12.5,2X,'Y7(1)=',E12.5,2X,'Y7(9)=',E12.5)
        STOP
      ELSE
      END IF
```

```
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      DTDER1=F7(I,J)
     >  +(F7(I+1,J)-F7(I,J))/(X7(I+1)-X7(I))*(R-X7(I))
      DTDER2=F7(I,J+1)
     >  +(F7(I+1,J+1)-F7(I,J+1))/(X7(I+1)-X7(I))*(R-X7(I))
      DTDER=DTDER1+(DTDER2-DTDER1)/(Y7(J+1)-Y7(J))*(E-Y7(J))
      FDTDER=DTDER
      RETURN
      END
      FUNCTION FDMUDRE(R,E)
      DR=0.01*R
      CALL UGAS3(E,R-DR/2.,ZMU1)
      CALL UGAS3(E,R+DR/2.,ZMU2)
      DMUDRE=(ZMU2-ZMU1)/DR
      FDMUDRE=DMUDRE
      RETURN
      END
      FUNCTION FDMUDER(R,E)
      DE=0.01*E
      CALL UGAS3(E-DE/2.,R,ZMU1)
      CALL UGAS3(E+DE/2.,R,ZMU2)
      DMUDER=(ZMU2-ZMU1)/DE
      FDMUDER=DMUDER
      RETURN
      END
      FUNCTION FDKDRE(R,E)
      DR=0.01*R
      CALL UGAS4(E,R-DR/2.,ZK1)
      CALL UGAS4(E,R+DR/2.,ZK2)
      DKDRE=(ZK2-ZK1)/DR
      FDKDRE=DKDRE
      RETURN
      END
      FUNCTION FDKDER(R,E)
      DE=0.01*E
      CALL UGAS4(E-DE/2.,R,ZK1)
      CALL UGAS4(E+DE/2.,R,ZK2)
      DKDER=(ZK2-ZK1)/DE
      FDKDER=DKDER
      RETURN
      END
      FUNCTION FAR(P,R,T,E,AMW)
      DMDRT=FDMDRT(R,T)
      DMDTR=FDMDTR(R,T)
      DTDRE=FDTDRE(R,E)
      BR=1.-R/AMW*DMDRT
      BT=1.-T/AMW*DMDTR
      FAR=P/R*BR+P/T*BT*DTDRE
      RETURN
      END
```

```
      FUNCTION FAE(P,R,T,E,AMW)
      DMDRT=FDMDRT(R,T)
      DMDTR=FDMDTR(R,T)
      DTDER=FDTDER(R,E)
      BR=1.-R/AMW*DMDRT
      BT=1.-T/AMW*DMDTR
      FAE=P/T*BT*DTDER
      RETURN
      END
      FUNCTION FCO2(P,R,T,E,AMW)
      COMPUTING OF SPEED OF SOUND - C**2
      P - PRESSURE
      R - DENSITY
      T - TEMPERATURE
      E - INTERNAL ENERGY
      AMW - MOLECULAR WEIGHT
      DMDRT=FDMDRT(R,T)
      DMDTR=FDMDTR(R,T)
      DTDRE=FDTDRE(R,E)
      DTDER=FDTDER(R,E)
      BR=1.-R/AMW*DMDRT
      BT=1.-T/AMW*DMDTR
      FCO2=P/R*BR+P/T*BT*(DTDRE+P/R**2*DTDER)
      RETURN
      END
      SUBROUTINE SUPPLY
*****************************************************************
*
*     SERVICE SUBROUTINE
*
*****************************************************************
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
     >        G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
     >        U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
     >        ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
     >        ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
     >        DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
     >        A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
     >        RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
     >        PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
     >        IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
     >            (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
      DIMENSION SS(4),A(4,4)
*****************************************************************
      ENTRY CHECK
*****************************************************************
      DO 10 K=1,4
   10 SS(K)=0.
      DO 20 I=2,IL
```

```
      DO 20 J=2,JL
      DO 20 K=1,4
      QQ=Q(I,J,K)
      IF(K.EQ.3) QQ=Q(I,J,2)
      IF(QQ.EQ.0.0) GO TO 20
      SS(K)=SS(K)+(DQ(I,J,K)*RJ(I,J)/Y(I,J)/QQ)**2
   20 CONTINUE
      DO 30 K=1,4
   30 SS(K)=SQRT(SS(K))/(IL*JL)
      WRITE (6,500) NADV,(SS(K),K=1,4)
  500 FORMAT(2X,'NADV=',I4,4X,'SS(1)=',1X,E12.7,
     >       2X,'SS(2)=',1X,E12.7,2X,'SS(3)=',1X,E12.7,
     >       2X,'SS(4)=',1X,E12.7)
      WRITE (10,501) NADV,(SS(K),K=1,4)
  501 FORMAT(I5,3X,4(1X,E14.7))
      RETURN
*****************************************************************
      ENTRY MASS
*****************************************************************
      PI=ACOS(-1.0)
      I=1
      FLRT=0.
      DO 41 J=1,JL1
      DR=SQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
      CXCY1=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCY2=SQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
      FLRT=FLRT+0.5*PI*(Y(I,J)+Y(I,J+1))*DR*
     >     (RHO(I,J)*UN(I,J)/CXCY1+RHO(I,J+1)*UN(I,J+1)/CXCY2)
   41 CONTINUE
      WRITE (6,502) I,FLRT
      WRITE (4,503) I,FLRT
      DO 40 I=1,IL1
      FLRT=0.
      DO 50 J=1,JL1
      DR1=SQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
      DR2=SQRT((X(I+1,J+1)-X(I+1,J))**2+(Y(I+1,J+1)-Y(I+1,J))**2)
      DR=0.5*(DR1+DR2)
*
*     1ST ORDER
*
      CXCY11=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCY12=SQRT(SAIX(I+1,J)**2+SAIY(I+1,J)**2)
      CXCY1=0.5*(CXCY11+CXCY12)
      CXCY21=SQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
      CXCY22=SQRT(SAIX(I+1,J+1)**2+SAIY(I+1,J+1)**2)
      CXCY2=0.5*(CXCY21+CXCY22)
      RHOUN1=0.5*(RHO(I,J)*UN(I,J)/CXCY11
     >           +RHO(I+1,J)*UN(I+1,J)/CXCY12)
      RHOUN2=0.5*(RHO(I,J+1)*UN(I,J+1)/CXCY21
     >           +RHO(I+1,J+1)*UN(I+1,J+1)/CXCY22)
      IF(I.EQ.IL1) GO TO 59
      CALL JCBABPM(1,1,1,A,I,J)
      AQ1=0.
      DO 51 JJ=1,4
   51 AQ1=AQ1+A(1,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))
```

```
      CALL JCBABPM(1,1,1,A,I,J+1)
      AQ2=0.
      DO 52 JJ=1,4
   52 AQ2=AQ2+A(1,JJ)*(Q(I+1,J+1,JJ)-Q(I,J+1,JJ))
      RHOUN1=RHOUN1-0.5*AQ1/CXCY1
      RHOUN2=RHOUN2-0.5*AQ2/CXCY2
      CALL JCBABPM(1,2,1,A,I,J)
      AQ1=0.
      DO 53 JJ=1,4
   53 AQ1=AQ1+A(1,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))
      CALL JCBABPM(1,2,1,A,I,J+1)
      AQ2=0.
      DO 54 JJ=1,4
   54 AQ2=AQ2+A(1,JJ)*(Q(I+1,J+1,JJ)-Q(I,J+1,JJ))
      RHOUN1=RHOUN1+0.5*AQ1/CXCY1
      RHOUN2=RHOUN2+0.5*AQ2/CXCY2
*
*     2ND ORDER
*
      IF(I.GT.1.AND.I.LT.IL1) THEN
        CXCY11=SQRT(SAIX(I-1,J)**2+SAIY(I-1,J)**2)
        CXCY12=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
        CXCY1=0.5*(CXCY11+CXCY12)
        CXCY21=SQRT(SAIX(I-1,J+1)**2+SAIY(I-1,J+1)**2)
        CXCY22=SQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
        CXCY2=0.5*(CXCY21+CXCY22)
        CALL JCBABPM(1,1,1,A,I-1,J)
        AQ1=0.
        DO 55 JJ=1,4
   55   AQ1=AQ1+A(1,JJ)*(Q(I,J,JJ)-Q(I-1,J,JJ))
        CALL JCBABPM(1,1,1,A,I-1,J+1)
        AQ2=0.
        DO 56 JJ=1,4
   56   AQ2=AQ2+A(1,JJ)*(Q(I,J+1,JJ)-Q(I-1,J+1,JJ))
        RHOUN1=RHOUN1+0.5*AQ1/CXCY1
        RHOUN2=RHOUN2+0.5*AQ2/CXCY2
        CXCY11=SQRT(SAIX(I+1,J)**2+SAIY(I+1,J)**2)
        CXCY12=SQRT(SAIX(I+2,J)**2+SAIY(I+2,J)**2)
        CXCY1=0.5*(CXCY11+CXCY12)
        CXCY21=SQRT(SAIX(I+1,J+1)**2+SAIY(I+1,J+1)**2)
        CXCY22=SQRT(SAIX(I+2,J+1)**2+SAIY(I+2,J+1)**2)
        CXCY2=0.5*(CXCY21+CXCY22)
        CALL JCBABPM(1,2,1,A,I+1,J)
        AQ1=0.
        DO 57 JJ=1,4
   57   AQ1=AQ1+A(1,JJ)*(Q(I+2,J,JJ)-Q(I+1,J,JJ))
        CALL JCBABPM(1,2,1,A,I+1,J+1)
        AQ2=0.
        DO 58 JJ=1,4
   58   AQ2=AQ2+A(1,JJ)*(Q(I+2,J+1,JJ)-Q(I+1,J+1,JJ))
        RHOUN1=RHOUN1-0.5*AQ1/CXCY1
        RHOUN2=RHOUN2-0.5*AQ2/CXCY2
      END IF
   59 CONTINUE
      Y1=0.5*(Y(I,J)+Y(I+1,J))
```

```
      Y2=0.5*(Y(I,J+1)+Y(I+1,J+1))
      FLRT=FLRT+0.5*PI*(Y1+Y2)*DR*(RHOUN1+RHOUN2)
   50 CONTINUE
      II=I+1
      WRITE (6,502) II,FLRT
  502 FORMAT(1X,'I=',I4,2X,'FLRT=',E14.7)
      WRITE (4,503) II,FLRT
  503 FORMAT(1X,I8,E14.7)
   40 CONTINUE
      RETURN
C*****************************************************************
      ENTRY OUTPUT
C*****************************************************************
      IF(IWRT.EQ.0) GO TO 60
      WRITE (6.504) NEND
  504 FORMAT(//4X,'NEND=',I5//)
      DO 70 I=1,IL
      WRITE (6,505) I
  505 FORMAT(//2X,2HI=,I2,4X,1HX,11X,1HY,11X,1HU,11X,1HV,11X,
     >       1HP,11X,1HR,11X,1HT,11X,1HE,11X,1HS,11X,1HM/)
      DO 70 J=1,JL
      RA=RHO(I,J)
      UA=RHOU(I,J)/RHO(I,J)
      VA=RHOV(I,J)/RHO(I,J)
      EOA=EO(I,J)
      EA=EOA/RA-0.5*(UA**2+VA**2)
      TA=FT(RA,EA)
      AMWA=FAMW(RA,TA)
      PA=RA*(RG/AMWA)*TA
      GAMMA=1.+(RG/AMWA)/(EA/TA)
      SA=ALOG(PA)/GAMMA-ALOG(RA)
      CO=SQRT(FCO2(PA,RA,TA,EA,AMWA))
      AMACH=SQRT(UA**2+VA**2)/CO
      WRITE (6,506) J,X(I,J),Y(I,J),UA,VA,PA,RA,TA,EOA,SA,AMACH
  506 FORMAT(2X,2HJ=,I2,10(1X,E11.4))
   70 CONTINUE
   60 CONTINUE
C
C     WRITING COMPUTED DATA ON TAPE
C
      WRITE (8) ((DELTAU(I,J),I=1,IL),J=1,JL)
      WRITE (8) ((RHO(I,J),RHOU(I,J),RHOV(I,J),EO(I,J),
     >       I=1,IL),J=1,JL)
      RETURN
      END
      SUBROUTINE EEL(J,MM,JMAX,E,EL,AM,BM,CM,DM,IN,AL,BE)
C*****************************************************************
C
C     LIBRARY SUBROUTINES
C
C*****************************************************************
      DIMENSION IN(MM),E(MM,MM,JMAX),EL(MM,JMAX)
      DIMENSION AM(MM,MM),BM(MM,MM),CM(MM,MM),DM(MM)
      DIMENSION AL(MM,MM),BE(MM)
      DO 1 M=1,MM
```

```
      TP=0.00
      DO 2 N=1,MM
      T1=0.00
      IF(J.EQ.1) GO TO 3
      TP=TP+AM(M,N)*EL(N,J-1)
      DO 4 K=1,MM
      T1=T1+AM(M,K)*E(K,N,J-1)
    4 CONTINUE
    3 CONTINUE
      AL(M,N)=BM(M,N)-T1
    2 CONTINUE
      EL(M,J)=DM(M)+TP
    1 CONTINUE
      DO 5 M=1,MM
      DO 6 N=1,MM
      E(M,N,J)=CM(M,N)
    6 CONTINUE
    5 CONTINUE
      CALL AXB(MM,MM,AL,E(1,1,J),BE,0,IN)
      CALL AXB(MM,1,AL,EL(1,J),BE,1,IN)
      RETURN
      END
      SUBROUTINE SOLU(W,JMAX,MM,E,EL)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      DIMENSION W(MM,JMAX),E(MM,MM,JMAX),EL(MM,JMAX)
      DO 1 M=1,MM
      W(M,JMAX)=EL(M,JMAX)
    1 CONTINUE
      DO 2 J1=2,JMAX
      J=JMAX+1-J1
      DO 3 M=1,MM
      SUM=0.00
      DO 4 K=1,MM
      SUM=SUM+E(M,K,J)*W(K,J+1)
    4 CONTINUE
      W(M,J)=SUM+EL(M,J)
    3 CONTINUE
    2 CONTINUE
      RETURN
      END
      SUBROUTINE AXB(N,M,A,B,X,INIT,IPS)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      DIMENSION A(N,N),B(N,M),IPS(N),X(N)
      IF(INIT.EQ.0) CALL DECOMP(N,A,IPS)
      DO 1 I=1,M
      CALL SOLV(N,A,B(1,I),X,IPS)
    1 CONTINUE
```

```
      RETURN
      END
      SUBROUTINE DECOMP(N,UL,IPS)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      DIMENSION UL(N,N),IPS(N)
      DO 1 I=1,N
      IPS(I)=I
    1 CONTINUE
      NM1=N-1
      DO 2 K=1,NM1
      BIG=0.00
      DO 3 I=K,N
      IP=IPS(I)
      SIZE=ABS(UL(IP,K))
      IF(SIZE-BIG) 3,3,4
    4 BIG=SIZE
      IDXPIV=I
    3 CONTINUE
      IF(IDXPIV-K) 5,6,5
    5 J=IPS(K)
      IPS(K)=IPS(IDXPIV)
      IPS(IDXPIV)=J
    6 KP=IPS(K)
      PIVOT=UL(KP,K)
      KP1=K+1
      DO 7 I=KP1,N
      IP=IPS(I)
      EM=-UL(IP,K)/PIVOT
      UL(IP,K)=-EM
      DO 7 J=KP1,N
      UL(IP,J)=UL(IP,J)+EM*UL(KP,J)
    7 CONTINUE
    2 CONTINUE
      RETURN
      END
      SUBROUTINE SOLV(N,UL,B,X,IPS)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      DIMENSION UL(N,N),B(N),X(N),IPS(N)
      NP1=N+1
      IP=IPS(1)
      X(1)=B(IP)
      DO 1 I=2,N
      IP=IPS(I)
      IM1=I-1
      SUM=0.00
      DO 2 J=1,IM1
      SUM=SUM+UL(IP,J)*X(J)
```

```
    2 CONTINUE
      X(I)=B(IP)-SUM
    1 CONTINUE
      IP=IPS(N)
      B(N)=X(N)/UL(IP,N)
      DO 3 IBACK=2,N
      I=NP1-IBACK
      IP=IPS(I)
      IP1=I+1
      SUM=0.00
      DO 4 J=IP1,N
      SUM=SUM+UL(IP,J)*B(J)
    4 CONTINUE
      B(I)=(X(I)-SUM)/UL(IP,I)
    3 CONTINUE
      RETURN
      END
      SUBROUTINE SZERO(M,A)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      SET ZERO FOR MATRIC (M,M)
      DIMENSION A(M,M)
      DO 1 I=1,M
      DO 1 J=1,M
      A(I,J)=0.00
    1 CONTINUE
      RETURN
      END
      SUBROUTINE SMM(M,C,A,B)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      SCALAR*METRIC (M,M)
      DIMENSION A(M,M),B(M,M)
      DO 1 I=1,M
      DO 1 J=1,M
      B(I,J)=C*A(I,J)
    1 CONTINUE
      RETURN
      END
      SUBROUTINE MMM(M,A,B,C)
*****************************************************************
*
*     LIBRARY SUBROUTINES
*
*****************************************************************
      METRIX*METRIX (M*M)
      DIMENSION A(M,M),B(M,M),C(M,M)
      DO 1 I=1,M
      DO 1 J=1,M
```

```
      C(I,J)=0.00
```